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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICANTS:	Albert *et al.*		
SERIAL NUMBER:	09/140,862	ART UNIT:	2673
FILING DATE:	August 27, 1998	EXAMINER:	David L. Lewis
TITLE:	Color Electrophoretic Displays		

SUPPLEMENTAL APPEAL BRIEF

Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

This is a Supplemental Appeal Brief in support of Appellants' Request for Reinstatement of the Appeal Under 37 C.F.R. § 1.193(b)(2) ("the Request for Reinstatement") filed concurrently herewith. A Notice of Appeal for this application was received by the United States Patent and Trademark Office on June 11, 2001, and an Appeal Brief for this application was filed on September 12, 2001.

The Request for Reinstatement is filed in response to the Office Communication mailed from the U.S. Patent and Trademark Office on December 4, 2001 ("the Post-Appeal Communication"), reopening prosecution of this application after consideration of Appellant's Appeal Brief filed September 12, 2001.

A three-month extension of time up to and including June 4, 2002, for filing the Request for Reinstatement and Supplemental Appeal Brief is respectfully requested. A petition for the extension of time and appropriate fee are being submitted concurrently herewith. Also submitted herewith is an Appendix presenting the claims on appeal, Exhibit A presenting evidence of the real party in interest, Exhibit B presenting evidence of the meaning of relevant terms, newly submitted Exhibit C presenting evidence of the meaning of terms made relevant by the Post-

Appeal Communication's new grounds for rejection, and attached as Exhibit D is a copy of the Appeal Brief filed September 12, 2001. The Supplemental Appeal Brief, Appendix, and Exhibits A-D are submitted in triplicate in accordance with 37 C.F.R. § 1.192(a).

(1) Real Party in Interest

The real party in interest in the above-identified patent application is E Ink Corporation. Assignments perfecting E Ink Corporation's interest in this application were submitted to the U.S. Patent and Trademark Office on March 11, 1999 and June 9, 1999. Copies of the Assignments, the Notices of Recordation of Assignment Document, and the PTO-stamped Recordation Form Cover Sheets are attached hereto as Exhibit A.

(2) Related Appeals and Interferences

To the best of the Appellants' knowledge, there are currently no related interferences. Appeals have been taken in United States Patent Application Serial No. 09/141,448, filed August 27, 1998 (Appeal Brief filed May 10, 2002), and United States Patent Application Serial No. 09/141,126, filed August 27, 1998 (Appeal Brief filed May 13, 2002), and may be considered related to the instant appeal

(3) Status of Claims

The claims on appeal are claims 1-9 of the instant application. Claims 1, 2 and 6 remain rejected under 35 U.S.C. §103(a) over United States Patent No. 3,756,693 to Ota et al. ("Ota '693") in view of Japanese patent abstract publication number JP 01086116 by Naoyuki ("Naoyuki")[1] and United States Patent No. 5,650,872 to Saxe ("Saxe"). Claims 3-5 and 7-9 remain rejected under 35 U.S.C. § 103(a) over Ota '693 in view of Naoyuki and United States Patent No. 3,870,517 to Ota et al. ("Ota '517"). The claims on appeal appear in the Appendix attached hereto.

[1] Appellants note that in a teleconference conducted on September 15, 2000, the Examiner confirmed that JP 01086116 was miscited by the Office as JP 401086111A. Appellants further note that the reference continues to be miscited in Patent Office communications subsequent to the September 15, 2000, conversation. Therefore, Appellants treat references to JP 401086111A as references to JP 01086116.

(4) Status of Amendments

Claims 1-10 were presented for examination. In a Final Office Action mailed from the U.S. Patent and Trademark Office on April 9, 2001, ("the Final Office Action") claims 1, 2 and 6 were rejected under 35 U.S.C. §103(a) as unpatentable over Ota '693 and Naoyuki. Claims 3-5 and 7-10 were rejected under 35 U.S.C. § 103(a) as unpatentable over Ota '693 in view of Naoyuki and Ota '517. Appellants submitted a Notice of Appeal to the United States Patent and Trademark Office, which was received on June 11, 2001. Appellants submitted an Appeal Brief on September 12, 2001 ("the Appeal Brief").

In an Office Communication mailed from the U.S. Patent and Trademark Office on December 4, 2001, ("the Post-Appeal Communication") the Examiner reopened prosecution. The Examiner allowed claim 10 but rejected claims 1, 2 and 6 under 35 U.S.C. §103(a) as unpatentable over Ota '693 in view of Naoyuki and Saxe. Claims 3-5 and 7-9 were rejected under 35 U.S.C. § 103(a) as unpatentable over Ota '693 in view of Naoyuki, Saxe and Ota '517.

(5) Summary of Invention

Appellants appeal the rejection of the invention claimed by claims 1-9. As defined by appealed claims 1, 2 and 6, Appellants invention relates to an electrophoretic display comprising at least one capsule (20), the capsule (20) includes one or more particles (50) and a suspending fluid (25), and at least two electrodes (30, 40) positioned adjacent the capsule. See, e.g., Specification, page 11, lines 22-27 and Figures 1A-1C. The capsule comprises at least a first particle having a first optical property and a first electrophoretic mobility. See, e.g., Specification, page 19, lines 23-26, and Figures 6, 7A-7B, 8A-8D, and 9A-9C. The application of an electric field to the capsule (20) by the electrodes (30, 40) causes the capsule (20) to change visual state in response to the optical properties and electrophoretic mobilities of the particles (e.g., R, G and B of Figures 6, 7A-7B, 8A-8D, and 9A-9C). Where the display has a first particle (e.g., B of Figures 7A -B) with a first electrophoretic mobility and a second particle (e.g., R or G of Figures 7A -B) with a second electrophoretic mobility, the first and the second electrophoretic mobility are, for example, substantially non-overlapping. See, e.g., Specification, page 20, lines 3-20, and Figures 7A-7B.

As defined by appealed claims 5, 8 and 9, Appellants invention also relates to an electrophoretic display comprising at least one capsule (20) having at least one particle (50) and a suspending fluid (25) and at least two electrodes (30, 40) disposed adjacent the at least one capsule (20). See, e.g., Specification, page 11, lines 22-27, and Figures 1A-1C. The suspending fluid may be dyed a color. See, e.g., Specification, page 12, line 14. A voltage potential applied to one of the electrodes causes particles to migrate within the capsule, changing the visual state of the capsule. See, e.g., Specification, page 18 lines 18-26. The at least one particle can have, for example, an optical property matching an optical property of one of the at least two electrodes. See, e.g., Specification, page 13, lines 20-21. The at least one particle may be, for example, a substantially white particle. See, e.g., Specification, page 19, line 7.

As defined by appealed claim 3, Appellants invention relates to an electrophoretic display comprising at least one capsule (20), the capsule (20) includes at least one red particle (R), at least one blue particle (B), and at least one green particle (G), a suspending fluid (25), and at least two electrodes (32, 34) positioned adjacent the capsule (20). See, e.g., Specification, page 20, lines 3-20, and Figures 6, 7A-7B, 8A-8D, and 9A-9C. The capsule (20) comprises at least a first particle having a first optical property and a first electrophoretic mobility and a second particle having a second optical property and a second electrophoretic mobility. See, e.g., Specification, page 19, lines 23-26. The application of an electric field to the capsule (20) by the electrodes (32, 34) causes the capsule (20) to change visual state in response to the optical properties and electrophoretic mobilities of the particles (R, G, and B). See, e.g., Specification, page 20, lines 3-20, and Figures 6, 7A-7B, 8A-8D and 9A-9C.

As defined by appealed claims 4 and 7, Appellants' invention relates to the electrophoretic displays described above in connection to claims 1 and 6, respectively, in which the suspending fluid is substantially transparent. See, e.g., Specification, page 12, line 12-13.

(6) Issues

1. The first issue presented for appeal is whether appealed claims 1, 2 and 6 are patentable under 35 U.S.C. § 103(a) over Ota '693 in view of Naoyuki and Saxe.

2. The second issue presented for appeal is whether appealed claims 5, 8 and 9 are patentable under 35 U.S.C. § 103(a) over Ota '693 in view of Naoyuki, Saxe and Ota '517.

3. The third issue presented for appeal is whether appealed claim 3 is patentable under 35 U.S.C. § 103(a) over Ota '693 in view of Naoyuki, Saxe and Ota '517.

4. The fourth issue presented for appeal is whether appealed claims 4 and 7 are patentable under 35 U.S.C. §103(a) over Ota '693 in view of Naoyuki, Saxe and Ota '517.

5. Although Appellants believe that the above-identified issues correspond to all of the pending rejections, Appellants also appeal any other bases for rejection of the pending claims which were not explicitly stated in the Final Office Action or the Post-Appeal Communication but which may be regarded as still pending.

(7) Grouping of Claims

The rejected claims 1-9 **do not** stand or fall together.

Claims 1, 2 and 6 stand or fall together.

Claims 5, 8 and 9 stand together.

Claim 3 stands alone.

Claims 4 and 7 stand together.

(8) Appellants' Argument

Appellants believe that there are no outstanding claim rejections under 35 U.S.C. §112, first or second paragraph. The following arguments address each of the issues presented for appeal. Appellants respectfully request reversal of the rejections of claims 1-9 under 35 U.S.C. § 103(a) because the references asserted by the Examiner do not teach or fairly suggest the inventions of Appellants' claims 1-9. Further, the references, evidence and arguments asserted by the Examiner fail to establish a *prima facie* case of obviousness against claims 1-9.

8.1 Claims 1, 2 and 6 are patentable over Ota '693 in view of Naoyuki and Saxe

Appellants respectfully request that the rejection of claims 1, 2, and 6 under 35 U.S.C. § 103(a) be reversed because the Examiner's combination of Ota '693, Naoyuki and Saxe is insufficient to establish either a *prima facie* case of obviousness or to maintain a rejection under 35 U.S.C. § 103(a). Three criteria must be met to establish a *prima facie* case of obviousness: (1) some suggestion or motivation to modify or combine the references; (2) a reasonable expectation of success; and (3) the combination must teach or fairly suggest all the claim limitations and the invention as a whole. See Graham v. John Deere Co., 383 U.S. 1, 17-18, 86 S.Ct. 684, 695-96, 148 U.S.P.Q. 459, 467 (1966); In re Vaeck, 947 F.2d 488, 493, 20 U.S.P.Q.2d 1438 (Fed. Cir. 1991); see also MPEP §§ 2142, 2143 (8th Ed., August 2001). The references asserted by the Examiner do not establish a *prima facie* case of obviousness because they fail to provide a reasonable expectation of success and they fail to teach or fairly suggest all the limitations of Appellants' claims. Specifically, Ota '693, Naoyuki and Saxe in view of the art do not teach or enable the ordinary artisan to produce Appellant's invention as a whole. Consequently, the references asserted by the Examiner are insufficient to establish a *prima facie* case of obviousness and cannot render Appellants' claims obvious.

It is well settled that a prior art reference must place any allegedly disclosed matter in the possession of one of ordinary skill in the art such that it is capable of being put into practical operation. See, e.g., Seymour v. Osborn, 78 U.S. 516, 555, 20 L.Ed. 33, 42 (1870); In re Brown, 51 C.C.P.A. 1254, 1259, 329 F.2d 1006, 1011 (CCPA 1964). A reference, or combination of references, that does not enable one of ordinary skill in the art to practice every limitation of a claim, and the claim as a whole, cannot render that claim obvious. See, e.g., MPEP § 2121.01 (8th Ed., August 2001). It follows that, if a reference, or combination of references, does not enable, then the ordinary artisan cannot have a reasonable expectation of successfully practicing the claimed invention. Enablement of a limitation requires a description that: "enable[s] any person skilled in the art to which it pertains ... to make and use the same." 35 U.S.C. § 112, 1st paragraph. Accordingly, a combination of references, in view of knowledge in the art, cannot render a claim limitation obvious or establish a *prima facie* case of obviousness if there is no description of how to make and use that limitation.

Appellants note that prior to the Post-Appeal Communication, the Examiner asserted Ota '693 and Naoyuki as the basis for his rejection of claims 1, 2 and 6. See Final Office Action at pages 2-3. In response to Appellants' Appeal Brief, the Examiner reopened prosecution and reasserted Saxe[2] against claims 1, 2 and 6 in combination with Ota '693 and Naoyuki to reject Appellants' claims. The Examiner's basis for using Ota '693 and Naoyuki against claims 1, 2 and 6, however, is verbatim that asserted in the Final Office Action. (Compare The Post-Appeal Communication at pages 3-4, with Final Office Action of April 9, 2001 at pages 2-3). Thus, Appellants, in accordance with MPEP § 1208.02, reassert and incorporate by reference their arguments with respect to claims 1, 2 and 6 as set forth in Appellants' Appeal Brief on pages 5-10 and 22-24. (a copy of the Appeal Brief is attached as Exhibit D).

Apparently, the Examiner agrees with Appellants' Appeal Brief that Ota '693 and Naoyuki do not render claims 1, 2 and 6 obvious and has added Saxe to cure the deficiences of Ota '693 and Naoyuki. Appellants' respectfully submit that Saxe does not cure the deficiencies of Ota '693 and Naoyuki. Either alone or in proper combination with Ota '693 and Naoyuki, Saxe fails to enable one of ordinary skill in the art to practice the "encapsulation" limitation of:

> [a]n electrophoretic display comprising: at least one capsule containing a suspending fluid and at least [one] particle,

as required by Applicants' claims 1, 2 and 6, with the "mobility" limitation of:

> wherein application of an electric field to said capsule ... causes said capsule to change visual state responsive to the ... electrophoretic mobilities of said particles,

as required, by claims 1 and 2, or the "migration" limitation of:

> wherein application of a voltage potential to one of said at least two electrodes causes said at least one particle to migrate within said capsule,

as required by claim 6.

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[2] Saxe has previously been asserted by the Examiner to reject claims 1 and 6 as anticipated, and combined with Ota '693 to reject claims 1 and 2 as obvious, however, the Examiner later withdrew these rejection in response to Appellants' remarks. The Examiner first asserted Saxe against Appellants' claims in an Office Action dated December 8, 1999. In a response filed March 3, 2000, Appellants did not amend claims 1, 2 or 6, but set forth how Saxe, alone or in combination with Ota '693, did not teach or suggest these claims as a whole. The Examiner maintained his rejection of claims 1, 2 and 6 in a Final Office Action dated May 23, 2000. In a Reply After Final Rejection filed July 23, 2000, Appellants did not amend claims 1, 2 or 6, and set forth again how Saxe, alone or in combination with Ota '693, did not teach or suggest these claims as a whole. In response to the Reply, the Examiner withdrew Saxe and reopened prosecution with a non-final Office Action dated August 29, 2000.

As previously set forth, Ota '693 does not mention capsulated particles or even suggest, "at least one capsule containing a suspending fluid and at least [one] particle," as required by Appellants' claims. Appellants maintain that enclosing particles between two electrodes does not constitute encapsulation of particles as that term is used in the application because Appellants' capsule is a structure and claim element distinct from the electrodes.

Naoyuki does not cure the deficiencies of Ota '693 because Naoyuki merely mentions capsulated particles but provides no enabling description of making or using the limitation of, "at least one capsule containing a suspending fluid and at least [one] particle," as set forth in Appellants' claims 1, 2 and 6. Absent some discussion of how to perform (i.e., make or use) Appellants' above "encapsulation" claim limitation, Naoyuki's mere mention of microencapsulation is simply a suggestion to try capsulated particles. Naoyuki's simple suggestion to try microencapsulation is insufficient to render that Appellants' "encapsulation" limitation obvious because one of ordinary skill in the art would have no reasonable expectation of successfully practicing Appellants' "electrophoretic display comprising: at least one capsule containing a suspending fluid and at least [one] particle."

Saxe does not cure the deficiencies of Ota '693 and Naoyuki because Saxe also does not provide an enabling description of making or using the limitation of, "at least one capsule containing a suspending fluid and at least [one] particle," where the visual statue of the display changes responsive to particle electrophoretic mobility and/or migration as set forth in Appellants' claims 1, 2 and 6. As used in the application and claims, and as understood by those of ordinary skill in the art, the term "electrophoretic mobility" refers to the average velocity per unit electric field of a particle towards a positive or negative electrode. For example, The National Institute of Standards and Technology defines "electrophoretic mobility" as, "the electrophoretic velocity per unit field strength...is positive if the particle moves toward lower potential and negative in the opposite direction..." The Use of Nomenclature in Dispersion Science and Technology (NIST Special Publication 960-3), 20 (V. A. Hackley et al. eds., August 2001) (copy attached as Exhibit C downloaded on May 24, 2002 <http://www.nist.gov/public_affairs/practiceguides/SP960-3.pdf>) (emphasis added). Accordingly, the visual state of

the displays of Appellants' claimed invention changes because the particles migrate in response to an electric field.

Saxe teaches only anisometric particles that respond to an electric field -not by migration- but by reorientation to become aligned. (see, e.g., Saxe, col. 1, lines 15-50, col. 2, lines 55-67, col. 3, lines 57-59, col. 4, lines 8-26, and Figs. 3 and 4, item 21). The "reorientation" of particles does not encompass "migration" as the terms are used in Appellants' claims, Saxe, or understood by those of ordinary skill in the art. Migration necessarily involves a translational motion as the term "migrate" is used in the application whereas orientation and alignment do not. For example, Webster's Ninth New Collegiate Dictionary defines "orient" as, "3: to cause the axes of the molecules of to assume the same direction" See Webster's Ninth New Collegiate Dictionary 832 (1984). This definition of "orient" is consistent with the understanding of the term by those of ordinary skill in the art and by Saxe. A particle can "orient," or align," simply through rotational motion -no translational motion is required, inherent or implied. In contrast, the term "migrate" as used in the application and the art requires translational motion, i.e., motion from one location to another -not just simple rotation. As a result, electrophoretic mobility and particle migration are both absent from and irrelevant to the teachings of Saxe. Accordingly, Saxe does not disclose or enable the encapsulation of particles that migrate to change the visual state of a display or that electrophoretic mobility is even a relevant property of Saxe's particles.

Saxe does not teach "encapsulating two or more species of particles ... of the electrophoretic migrating type, column 3, lines 20-25, column 7 lines 55-64" as asserted by the Examiner because Saxe nowhere provides an enabling disclosure of encapsulating such particles. (The Post-Appeal Communication , at page 4). Although Saxe at column 3, lines 20-25, mentions in one sentence that "the electro-optical device according to the invention may ...utilize particle suspensions...wherein the particles are electrically caused to move between electrodes," this is the entire extent of Saxe's discussion of non-anisometric particles. This mere mention of non-anisometric particles does not constitute a teaching of encapsulating particles of the electrophoretic migrating type because it is not an enabling disclosure of encapsulating such particles.

The Examiner's use of one sentence of Saxe to conclude that Saxe teaches or even fairly suggests "encapsulating two or more species of particles ... of the electrophoretic migrating type" is an improper reading and use of Saxe. It is well settled that "pick[ing] and choos[ing] from one reference only so much of it as will support a given position to the exclusion of other parts necessary to the full appreciation of what such reference fairly suggests" is impermissible as a basis for rejecting a claims as obvious under 35 U.S.C. § 103. Bausch & Lomb, Inc. v. Barnes-Hind/Hydrocurve, Inc., 796 F.2d 443, 448, 230 U.S.P.Q. 416 (Fed. Cir. 1986) (quoting In re Wesslau, 353 F.2d 238, 241, 147 U.S.P.Q. 391, 393 (C.C.P.A. 1965)). Saxe does not fairly suggest "encapsulating two or more species of particles ... of the electrophoretic migrating type" because a full reading of Saxe shows that electrophoretic mobility and particle migration are irrelevant to its teachings. One of ordinary skill in the art on reading Saxe as a whole would readily understand Saxe to teach and fairly suggest only the use of anisometric particles of the rotating type. For example, Saxe at column 13, lines 40-44, states,

> It should be noted that a light valve suspension can comprise more than one type of particle. Thus two or more different pigments or other types of particles may be combined in any useful proportions to form suspensions having a vast number of different off-state colors.

The plain meaning of this passage indicates that Saxe is discussing only particles that align in response to an electric field -not particles which migrate- because in an electrophoretic system one cannot simply mix two pigments to achieve a mixture of the relevant colors as Saxe suggests. Rather, in an electrophoretic system electrophoretic mobility will determine the color of the display because electrophoretic mobility determines which species of particles moves to the front of the display upon application of an electrical field. Accordingly, when Saxe read as a whole, it is evident that Saxe does not support the Examiner's position that Saxe teaches "encapsulating two or more species of particles ... of the electrophoretic migrating type."

In short, Ota '693, Naoyuki and Saxe, either alone or in proper combination, do not enable one of ordinary skill in the art to provide capsulized particles that may migrate upon application of a voltage potential or that may change the visual state of the capsule responsive to the electrophoretic mobilities of the particles because these references in view of the art do not provide any description of how to encapsulate such particles. To establish obviousness requires

a showing that the prior art provides every limitation of a claim and the invention as a whole. See MPEP §§ 2142, 2143. Absent some discussion of how to perform a claim limitation, the mere mention of a limitation is simply a suggestion to try. A simple suggestion to try a limitation of a claim is insufficient to render that limitation obvious because one of ordinary skill in the art would have no reasonable expectation of successfully practicing the non-enabled limitation. The Examiner's combination of Ota '693 with Naoyuki and Saxe to produce Appellants' claims 1, 2 and 6 is thus improper, fails to establish a *prima facie* case of obviousness, and the rejection of claims 1, 2 and 6, under 35 U.S.C. § 103(a) should not be maintained. Therefore, Appellants respectfully request reversal of the rejection of claims 1, 2 and 6.

8.2 Claims 5, 8 and 9 are patentable over Ota '693 in view of Naoyuki, Saxe and Ota '517

Appellants note that, except for the conclusory heading "Claims 3-5, and 7-9 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ota (3756693) in view of Naoyuki (JP401086111A), Saxe et al. (5650872), and Ota et al. (3870517)," the Post-Appeal Communication provides no new grounds for rejection of claims 5, 8 and 9. (The Post-Appeal Communication of December 4, 2002 at page 5). As shown in the table below, the Examiner's basis for asserting that the added limitations of claims 5, 8 and 9 do not render these claims patentable is verbatim that asserted in the Final Office Action. Accordingly, Appellants, in accordance with MPEP § 1208.02, reassert and incorporate by reference their arguments with respect to claims 5, 8 and 9 as set forth in Appellants' Appeal Brief on pages 10-11 and 22-24. (a copy of the Appeal Brief is attached as Exhibit D).

Examiner's Asserted Basis for Rejection of Claims 5, 8 and 9

in Post-Appeal Communication (at page 5)	*in Final Office Action (at pages 3-4)*
"**As in claim 5**, Ota (517) teaches of the suspending medium being dyed, column 7 lines 15-22. **As in claim 8**, Ota (693) teaches of a color coated transparent electrode, column 8 lines 10-20, and a colored particle of optical reflective color and/or luminescent property, column 4 lines 54-67, wherein depending on the background/foreground color scheme desired the particle would obviously be the	"**As in claim 5**, Ota (517) teaches of the suspending medium being dyed, column 7 lines 15-22. **As in claim 8**, Ota (693) teaches of a color coated transparent electrode, column 8 lines 10-20, and a colored particle of optical reflective color and/or luminescent property, column 4 lines 54-67, wherein depending on the background/foreground color scheme desired the particle would obviously be the

have [sic] the same optical property as the electrode to hide the particles in a non-display voltage state, column 5 lines 16-37. **As in claim 9**, Ota (517) teaches of the at least one particle being white, column 7 lines 17-30, wherein the colorless suspending fluid can obviously be made white by a white particle used as a dye means to achieved [sic] the desired color, figure 3a item 15."	have [sic] the same optical property as the electrode to hide the particles in a non-display voltage state, column 5 lines 16-37. **As in claim 9**, Ota (517) teaches of the at least one particle being white, column 7 lines 17-30, wherein the colorless suspending fluid can obviously be made white by a white particle used as a dye means to achieved [sic] the desired color, figure 3a item 15."

Appellants respectfully submit that claims 5, 8 and 9 are patentable because Ota '517, Ota '693 and Naoyuki, either alone or in proper combination, do not provide an enabling disclosure of making or using the "encapsulation" limitation of: "at least one capsule containing a suspending fluid and at least [one] particle," with either the "mobility" limitation of claim 5 or the "migration" limitation of claims 8 and 9. To establish obviousness requires a showing that the prior art provides every limitation of a claim and the invention as a whole. See Graham, 383 U.S. at 17-18, 86 S.Ct. at 695-96, 148 U.S.P.Q. at 467; In re Royka, 490 F.2d at 985; see also MPEP §§ 2142, 2143 (8th Ed., August 2001). Accordingly, Appellants respectfully request reversal of the rejection of claims 5, 8 and 9.

For the reasons described above with respect to claims 1, 2, and 6, Appellants submit that Ota '693, Naoyuki and Saxe fail to teach or fairly suggest the above "encapsulation," "mobility" and "migration" limitations as set forth in Appellants' claims 5, 8 and 9, and that Ota '517 fails to provide the missing teachings. Specifically, Appellants submit that Ota '517's enclosure of particles between two electrodes does not teach or fairly suggest, "at least one capsule containing a suspending fluid and at least [one] particle," because Appellants' capsule is a structure and claim element distinct from the electrodes. Specifically, in relevant part, Appellants' claims 5, 8 and 9 require:

> An electrophoretic display comprising:
> at least one capsule..; and
> at least two electrodes disposed adjacent [said] capsule;

(emphasis added). Appellants thus submit that Ota '517 does not disclose a capsule, but rather unencapsulated particles disposed between electrodes. (See, e.g., Ota '517, col. 2, lines 46-55, see also Figs. 1a-1d, 2a-2b, 3a-3b, 4, and col. 8, lines 3-48, noting that item number 12 is porous

to particle passage). Accordingly, Ota '517 does not disclose a "capsule" that is separate and distinct from the electrodes because in Ota '517 the electrodes themselves are the walls that enclose the electrophoretic material. As a result, Ota '517 does not disclose "electrodes disposed adjacent [said] capsule" as set forth in Appellants' claims 5, 8 and 9.

Thus, for the reasons described above, Appellants respectfully submit that claims 5, 8 and 9, are novel and nonobvious over Ota '693 in view of Naoyuki, Saxe and Ota '517 because these references, either alone or in proper combination, do not teach, fairly suggest or enable one of ordinary skill in the art to practice every limitation of these claims. Moreover, for the reasons above, Appellants submit that the Examiner has failed to establish a *prima facie* case of obviousness against claims 5, 8 and 9. Therefore, Appellants respectfully request reversal of the rejection of claims 5, 8 and 9.

8.3 Claim 3 is patentable over Ota '693 in view of Naoyuki, Saxe and Ota'517

Appellants note that, except for the conclusory heading "Claims 3-5, and 7-9 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ota (3756693) in view of Naoyuki (JP401086111A), Saxe et al. (5650872), and Ota et al. (3870517)," the Post-Appeal Communication provides no new grounds for rejection of claim 3. (The Post-Appeal Communication of December 4, 2002 at page 5). As shown in the table below, the Examiner's basis for asserting that the added limitations of claim 3 do not render this claim patentable is verbatim that asserted in the Final Office Action. Accordingly, Appellants, in accordance with MPEP § 1208.02, reassert and incorporate by reference their arguments with respect to claim 3 as set forth in Appellants' Appeal Brief on pages 12-15 and 22-24. (a copy of the Appeal Brief is attached as Exhibit D).

Examiner's Asserted Basis for Rejection of Claim 3

in Post-Appeal Communication (at page 5)	*in Final Office Action (at page 3)*
"**As in claim 3**, Ota (693) in view of Naoyuki teaches of the invention as applied to claim 1 above. Further Ota et al. (517) demonstrates how the two particles can be three in number and of varying colors, column 2 lines 55-68, and since particles can act as the primary image colorant the skilled artisan could	"**As in claim 3**, Ota (693) in view of Naoyuki teaches of the invention as applied to claim 1 above. Further Ota et al. (517) demonstrates how the two particles can be three in number and of varying colors, column 2 lines 55-68, and since particles can act as the primary image colorant the skilled artisan could

obviously choose red, blue, and green as the particle colors well known as the prime colors in a colored spectrum display system."	obviously choose red, blue, and green as the particle colors well known as the prime colors in a colored spectrum display system."

Appellants respectfully request that the rejection of claim 3 under U.S.C. §103(a) be reversed, because the references asserted by the Examiner, either alone or in proper combination, also do not disclose or fairly suggest an electrophoretic display comprising "at least one capsule which includes at least one red, at least one blue and at least one green particle," as required by Appellants' claim 3. In particular, the teachings of Ota '517 are technologically incompatible with the use of red, green, and blue particles. As a result, the use of red, green and blue particles in Ota '517 would either change the basic principle under which the display of Ota '517 operates or render the display of Ota '517 inoperable for its intended purpose. A reference cannot be properly modified to render a claim obvious under 35 U.SC. § 103(a) or establish a *prima facie* case of obviousness when such a modification would change the principle of operation of the reference or render it inoperable for its intended purpose. See In re Gordon, 733 F.2d 900, 902, 221 U.S.P.Q. 1125 (Fed, Cir, 1984); In re Ratti, 270 F.2d 810, 813, 123 U.S.P.Q. 349, 352 (CCPA 1959). Accordingly, the modification of Ota '517 in combination with Ota '693 and Naoyuki to produce Appellants' claim 3 is improper, and the rejection of claim 3 under 35 U.S.C. § 103(a) should not be maintained.

In the Post-Appeal Communication rejection of claim 3 under 35 U.S.C. § 103(a), the Examiner reasserted verbatim his prior conclusions that: "Ota (517) demonstrates how the two particles can be three in number and of varying colors...and since the particles can act as the primary image colorant the skilled artisan could obviously choose red, blue, and green as the particle colors." (The Post-Appeal Communication at page 5; cf. Final Office Action of April 9, 2001 at page 3; cf. also Office Action of August 29, 2000 at page 3). In the Post-Appeal Communication, (as in the Final Office Action) the Examiner did not address the arguments made by Appellants in their Appeal Brief regarding the technological incompatibility of Ota '517 with the use of red, green, and blue particles as defined by Appellants claim 3. The Examiner simply ignored the technological incompatibility of using of red, green, and blue particles in Ota '517 with the stereotyped expression, "Applicant's arguments with respect to claims 1-9 have

been considered but are moot in view of the new ground(s) of rejection". (The Post-Appeal Communication at page 6).

It is well settled that the added limitations of a dependent claim may render it patentable even if the claim from which it depends is not. Consequently, even assuming arguendo that claim 1 is rendered obvious by the Examiner's readdition of Saxe to reject Appellants' claims, the mere assertion of Saxe against claim 1 does not render claim 3 obvious. Accordingly, Appellants submit that the arguments set forth in the Appeal Brief with respect to claim 3 are not moot in view of the allegedly new grounds for rejection of this claim because the Examiner's basis for asserting that the added limitations of claim 3 do not render it patentable is verbatim the basis he set forth in the Final Office Action.

Appellants maintain that the teachings of Ota '517 are technologically incompatible with the use of red, green, and blue particles as set forth in claim 3 and nothing in Ota '693, Naoyuki or Saxe cures this technological incompatibility. Consequently, the references asserted by the Examiner, either alone or in combination, would not motivate one of ordinary skill in the art to combine and modify these references to produce a display comprising a capsule having red, green, and blue particles as set forth in Appellants' claim 3.

The technological teachings of Ota '517 teach choosing particles that have a photosensitive response to certain colors of light. (See, e.g., Ota '517, col. 3, line 55 to col. 4, line 5; col. 6, lines 33-66). To understand the display disclosure of Ota '517, it is important to realize the difference between a color (i.e., what a human eye perceives) and a color of light (i.e., a discrete, continuous electromagnetic spectrum wavelength range). For example, it is common knowledge that there is no "white color of light," rather the color we see as white is actually a combination of all the visible colors of light. Accordingly, the principle of operation of a photosensitive particle consists of responding to a color of light, not to colors. In contrast, Appellants' claimed invention does not require a photosensitive response on the part of its electrophoretic particles to work.

Specifically, Ota '517 is directed towards a, "photoelectrophoretic color image reproduction panel" (col. 2, lines 43-44) wherein, "[t]he [electrophoretic] material 6 consists of at least three kinds of photosensitive electrophoretic materials 6a, 6b and 6c, the colors of which

are cyan, magenta and yellow, respectively, and have photosensitive response to red, green and blue light, respectively," (col. 2, lines 58-63)(emphasis added). The display of Ota '517 operates based on the principle of a photosensitive response to input light by particles that respond to their complementary color of light. For example, Ota '517 discloses that the cyan particles (e.g., item 6a) respond to red light, the magenta particles (e.g., item 6b) respond to green light, and the yellow particles (e.g., item 6c) respond to blue light. One of ordinary skill in the art, upon reading Ota '517, would understand that his particles are cyan, magenta and yellow because these colors are complementary to the light to which the particles are photosensitive. (See, e.g., Ota '517, col. 3, line 52 to col. 4, line 5). Further, the ordinary artisan would understand that Ota '517's choice of particle color is not open ended, but rather, dictated by the principle of operation of his display, i.e., the need for a photosensitive response to a color of light. As a result, the technological teaching of Ota '517 makes clear that the colors of his particles are not mere design choices; rather, the particle colors are central to the very principle of operation of his display.

Ota '517's teachings of a display using particle colors that are photosensitive to a complementary light color teaches away from, and are technologically incompatible with, red, green and blue particles because there are no colors of light that are complementary to these particle colors. That the technological teaching of Ota '517 are incompatible with red, blue and green particles can be illustrated by the following example. For example, there is no color of light that is complementary to a green particle color. The color complementary to green is magenta. However, there is no color of light that is magenta because the color magenta is actually a combination of light from both the blue and the red portions of the electromagnetic spectrum. As is well know, red and blue are at opposite ends of the visible portion of the electromagnetic spectrum and are separated by at least the green part of the spectrum. Accordingly, if magenta light is input into a display as taught by Ota '517 that has been modified to use red, green and blue particles, there can be no reasonable expectation that the display will work for its intended purpose based on the technological teachings of Ota '517. The so modified display of Ota '517 cannot be expected to work because it is not clear which of the red, green and blue particles (if any) will exhibit a photosensitive response to the magenta light which is actually composed of two colors of light, red and blue. Will the green particle respond? What if

the input light is just red, does the green particle still respond? What if the input light is just blue, does the green particle still respond? If the green particle responds to just red and just blue light how does the display distinguish between red and blue so that it is not "color blind"? That these questions could not be answered by one of ordinary skill in the art based on the technological teachings of Ota '517 serves to further illustrate that the technological teachings of Ota '517, which rely on a photosensitive response, cannot be modified to use red, green, and blue particles.

Consequently, Ota '517 inherently teaches away from the use of red, green and blue particles as set forth in Appellants' claim 3 because these colors of particles will not work in the technology taught by Ota '517. Moreover, one of ordinary skill in the art would have no reasonable expectation of successfully using the teachings of Ota '517 with red, green and blue particles and, in fact, would reasonably expect use of red, green and blue particles to render Ota '517 inoperable. As a result, one of ordinary skill in the art having found Ota '517 would have no motive to use its teachings to modify any other reference to have red, green and blue electrophoretic particles, and could not do so, because the teachings of Ota '517 fundamentally will not work with red, green and blue particles. Therefore, claim 3 is non-obvious over the art asserted by the Examiner because the asserted references fail to provide the limitation of, "at least one red particle, at least one blue particle, and at least one green particle," set forth in claim 3 and fail to teach the invention of claim 3 as a whole.

Thus, for the reasons described above, Appellants respectfully submit that claim 3 is novel and nonobvious over Ota '693 in view of Naoyuki, Saxe and Ota '517 because these references, either alone or in proper combination, do not teach or suggest the limitation of, "wherein said capsule contains at least one red particle, at least one blue particle, and at least one green particle," required by Appellants' claim 3. Moreover, for the reasons above, Appellants submit that the Examiner has failed to establish a *prima facie* case of obviousness against claim 3. Therefore, Appellants respectfully request reversal of the rejection of claim 3.

8.4 Claims 4 and 7 are patentable over Ota '693 in view of Naoyuki, Saxe and Ota '517

Appellants note that, except for the conclusory heading "Claims 3-5, and 7-9 are rejected under 35 U.S.C. 103(a) as being unpatentable over Ota (3756693) in view of Naoyuki

(JP401086111A), Saxe et al. (5650872), and Ota et al. (3870517)," the Post-Appeal Communication provides no new grounds for rejection of claims 4 and 7. (The Post-Appeal Communication of December 4, 2002 at page 5). As shown in the table below, the Examiner's basis for asserting that the added limitations of claims 4 and 7 do not render these claims patentable is verbatim that asserted in the Final Office Action. Accordingly, Appellants, in accordance with MPEP § 1208.02, reassert and incorporate by reference their arguments with respect to claims 4 and 7 as set forth in Appellants' Appeal Brief on pages 15-18 and 22-24. (a copy of the Appeal Brief is attached as Exhibit D).

Examiner's Asserted Basis for Rejection of Claims 4 and 7

in Post-Appeal Communication (at page 5)	*in Final Office Action (at page 3)*
"**As in claims 4 and 7**, Ota (517) teaches of a suspending fluid being transparent, column 4 lines 15-22, wherein colorless obviously implies transparent, column 1 lines 20-25."	"**As in claims 4 and 7**, Ota (517) teaches of a suspending fluid being transparent, column 4 lines 15-22, wherein colorless obviously implies transparent, column 1 lines 20-25."

Appellants respectfully request that the rejection of claims 4 and 7 under 35 U.S.C. § 103(a) be reversed because the references asserted by the Examiner cannot be properly combined to disclose or fairly suggest an electrophoretic display with a "suspending fluid that is substantially transparent" as required by Appellants' claim 4 and 7. Rather, the Ota '517 reference relied on by the Examiner as disclosing a transparent suspending fluid actually teaches away from use of such a fluid in an electrophoretic display. There can be no suggestion to combine a reference with another if the reference teaches away from the combination. See Tec Air, Inc. v. Denso Mfg. Michigan, Inc., 192 F.3d 1353, 1359-60, 52 U.S.P.Q.2d 1294 (Fed. Cir. 1999); In re Fine, 837 F.2d 1071, 1075, 5 U.S.P.Q. 1596, 1599 (Fed. Cir. 1988). As a result, there is nothing in the cited references that would suggest to one of ordinary skill in the art to combine a transparent suspending fluid with an electrophoretic display to produce the invention of claims 4 and 7. In addition, the Examiner has provided no facts or arguments to show that the nature of the problem or the knowledge of one of ordinary skill in the art would suggest the combination of Ota '517 with Ota '693 and Naoyuki. Absent a suggestion in the prior art to combine references, a rejection under 35 U.S.C. § 103(a) based on the combined references cannot be maintained. See In re Dembiczak, 175 F.3d 994, 999, 1000, 50 U.S.P.Q.2d 1614,

(Fed. Cir. 1999)(abrogated in part on other grounds). Accordingly, the combination of Ota '517 with of Ota '693 and Naoyuki to suggest Appellants' invention is improper, and do not establish a *prima facie* case of obviousness against claims 4 and 7. Thus, the rejection of claims 4 and 7 under 35 U.S.C. § 103(a) should be reversed.

In the Post-Appeal Communication rejection of claims 4 and 7 under 35 U.S.C. § 103(a) the Examiner reasserted verbatim his prior conclusion that: "[a]s in claims 4 and 7, Ota (517) teaches of a suspending fluid being transparent, column 4 lines 15-22, wherein colorless obviously implies transparent, column 1 lines 20-25." (Final Office Action of April 9, 2001 at page 3; cf. Office Action of August 29, 2000 at page 3). The Examiner did not address the arguments made by Appellant's in their Appeal Brief with respect to the Examiner's use of Ota '517 against these claims except to respond with the stereotyped expression, "Applicant's arguments with respect to claims 1-9 have been considered but are moot in view of the new ground(s) of rejection". (The Post-Appeal Communication at page 6).

It is well settled that the added limitations of a dependent claim may render it patentable even if the claim from which it depends is not. Consequently, even assuming arguendo that claims 1 and 6 are rendered obvious by the Examiner's readdition of Saxe to reject Appellants' claims, the mere assertion of Saxe against claim 1 or 6 does not render, respectively, claim 4 or 7 obvious. Accordingly, Appellants submit that the arguments set forth in the Appeal Brief with respect to claims 4 and 7 are not moot in view of the allegedly new grounds for rejection of this claim because the Examiner's basis for asserting that the added limitations of claims 4 and 7 do not render these claims patentable is verbatim the basis set he forth in the Final Office Action.

Appellants respectfully submit that Ota '517 cannot be properly combined with Ota '693 and Naoyuki to reject claims 4 and 7 under 35 U.S.C. § 103(a) because Ota '517 teaches away from claims 4 and 7 as a whole. A reference "teaches away" when one of ordinary skill in the art, on reading the reference, would be discouraged from following the path set forth by the applicant, or would be led in a divergent direction from the path taken by the applicant. See Tec Air, 192 F.3d at 1359-60; In re Fine, 837 F.2d at 1075. A reference can discourage an artisan from following an applicant's path by indicating the claimed combination would not work. Id. In particular, the passage of Ota '571 at column 4, lines 15-22, cited by the Examiner to support

his conclusion does not suggest use of a transparent suspending fluid because this passage discloses that a colorless suspending fluid will not work with the teachings of Ota '517.

Specifically, Ota '517 at col. 4, lines 15-22, states:

> at both electrodes 8 and 9, one can observe a positive color image at the electrode 8 and a negative color image at the electrode 9. The material 6 and the suspending medium 7a both act as colorant in the reproduced image. If the suspending medium 7a is colorless, both of the areas subjected to black light or white light will have the same color, that is, a black color at both electrodes 8 and 9 in FIG. 1c.

(emphasis added). Far from suggesting a transparent suspending medium, this passage discloses that a colorless suspending medium will not work because if the fluid is colorless both black and white light have the same color in the image, i.e., there will be no contrast, the image will be black. Accordingly, Ota '517 at col. 4, lines 15-22, leads one of ordinary skill in the art away from the idea of combining a transparent suspending fluid in an electrophoretic display by teaching that this combination renders his electrophoretic display inoperable.

Similarly, the passage of Ota '517 at column 1, lines 20-25, cited by the Examiner does not provide a suggestion to combine a transparent suspending fluid with an electrophoretic display. Instead, the entire content of Ota '517 leads one of ordinary skill in the art in a direction divergent to that of claims 4 and 7 by focusing on colored suspending media. Specifically, Ota '517 at col. 1, lines 20-36, states:

> According to these prior art methods, charged particles in a colorless suspending medium are transported to the surface of an electrode so as to reproduce a pattern corresponding to that of an input light image. The visible color image can be obtained by removing the electrode from the surface of the suspension, so that the suspension can not be enclosed in a housing. The particles act as the primary image colorant but the suspending medium does not because it is not colored. That is, the prior art does not seek to bring about a variation in the optical reflective property of a suspension itself due to a change in the spatial distribution of photosensitive particles in the suspension. Therefore, the prior art relates essentially to the reproduction of a permanent visible image but not to a changeable color display system.

(emphasis added). There is nothing in this passage to motivate or suggest the selection and use of the mentioned colorless suspending medium in an electrophoretic display to produce

Appellants' claimed combination. On the contrary, the entire context of the remainder of Ota '517 teaches away from a colorless suspending medium by focusing exclusively on use of colored suspending media for electrophoretic displays. See, e.g., col. 1, lines 44-47 (disclosing "photosensitive electrophoretic materials ... suspended in a white colored suspending medium"); col. 7, lines 18-21 (teaching "colored suspending medium 7a"); col. 8, lines 57-59 (teaching "colored suspending medium 7c"); col. 9, lines 50-52 (stating "[t]he electrophoretic suspension layer in accordance with the present invention having a white suspending medium"). As a result, there is no suggestion or motivation in Ota '517 to combine his mention of a colorless suspending medium with either Ota '693 or Naoyuki to produce the invention of Appellants' claims 4 and 7. Furthermore, the Examiner has provided no facts or arguments to show that the nature of the problem or the knowledge of one of ordinary skill in the art suggested the combination of Ota '517 with Ota '693, Naoyuki and/or Saxe. Accordingly, absent Appellants' application, there is no motivation to combine Ota '517 with either Ota '693, Naoyuki or Saxe to produce either claim 4 or 7.

Thus, for the reasons described above, Appellants respectfully submit that claims 4 and 7 are novel and nonobvious over Ota '693 in view of Naoyuki, Saxe and Ota '517 because these references, either alone or in proper combination, do not teach or suggest an, "electrophoretic display ... wherein said suspending fluid is substantially transparent," as required by claims 4 and 7. Moreover, for the reasons above, Appellants submit that the Examiner has failed to establish a *prima facie* case of obviousness against claims 4 and 7. Therefore, Appellants respectfully request reversal of the rejection of claims 4 and 7.

8.5 The claimed invention is patentable under any other possible bases for rejection.

Appellants believe that the foregoing arguments address each of the pending rejections of the pending claims. In particular, the present Supplemental Appeal Brief addresses each of the grounds for rejections made in the Post-Appeal Communication. Accordingly, Appellants submit that the present application meets all requirements for patentability.

(9) Conclusion

For the reasons given above, it is respectfully requested the final rejections be reversed and the application be passed to issue with claims 1-9 as presented in the Appendix attached hereto and claim 10 as currently allowed and pending in the present application.

A Transmittal for the filing of this Supplemental Appeal Brief, as well as a Petition and Fee for a three-month extension of time are submitted herewith. Appellants believe that the present filing necessitates no other fees. However, if any additional fees are due, the Commissioner is hereby authorized to charge any such fees to Attorney's Deposit Account No. 20-0531.

Respectfully submitted,

Date: June 4, 2002
Reg. No. 47,411
Tel. No. (617) 248-7102
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2340549v1

APPENDIX

1. An electrophoretic display comprising:

at least one capsule containing a suspending fluid and at least a first particle and a second particle, said first particle having a first optical property and a first electrophoretic mobility and said second particle having a second optical property and a second electrophoretic mobility; and

at least two electrodes disposed adjacent said capsule;

wherein application of an electric field to said capsule by said electrodes causes said capsule to change visual state responsive to the optical properties and electrophoretic mobilities of said particles.

2. The electrophoretic display of claim 1 wherein said first electrophoretic mobility and said second electrophoretic mobility are substantially non-overlapping.

3. The electrophoretic display of claim 1 wherein said capsule contains at least one red particle, at least one blue particle, and at least one green particle.

4. The electrophoretic display of claim 1 wherein said suspending fluid is substantially transparent.

5. The electrophoretic display of claim 1 wherein said suspending fluid is dyed.

6. An electrophoretic display comprising:

a substrate;

at least one capsule containing a suspending fluid and at least one particle;

at least two electrodes disposed adjacent the at least one capsule, said at least two electrodes disposed between said substrate and said at least one capsule,

wherein application of a voltage potential to one of said at least two electrodes causes said at least one particle to migrate within said capsule, causing said capsule to change its visual state.

7. The electrophoretic display of claim 6 wherein said suspending fluid is substantially transparent.

8. The electrophoretic display of claim 6 wherein said at least one particle has an optical property matching an optical property of one of said at least two electrodes.

9. The electrophoretic display of claim 6 wherein said at least one particle is substantially white.

2340549_1

EXHIBIT A

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DOC DATE: 06/07/1999

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SERIAL NUMBER: 09140862
FILING DATE: 08/27/1998
PATENT NUMBER:
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Name of Person Signing

Joseph B Milstein
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JOSEPH B. MILSTEIN	Joseph B Milstein	June 9, 1999
Name of Person Signing	Signature	Date

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Attorney Docket No. INK-006
(2108/13)

ASSIGNMENT

WHEREAS, I, Joseph Jacobson, have invented one or more improvements in

Color Electrophoretic Displays

described in an application (or provisional application) for Letters Patent of the United States:

☐ identified by Attorney Docket No. _____, and/or executed by me of even date herewith and about to be filed in the United States Patent Office;

☒ Serial No. 09/140,862 filed in the United States Patent Office on August 27, 1998; and

WHEREAS, E Ink Corporation (hereinafter "ASSIGNEE"), a corporation organized and existing under the laws of the State of Delaware, and having a usual place of business at 45 Spinelli Place, Cambridge, Massachusetts 02138 desires to acquire an interest therein, in accordance with agreements duly entered into with me;

NOW, THEREFORE, to all whom it may concern be it known that for and in consideration of said agreements and of other good and valuable consideration, the receipt of which is hereby acknowledged, I have sold, assigned and transferred and by these presents do hereby sell, assign and transfer unto said ASSIGNEE, its successors, assigns, and legal representatives, my entire right, title and interest in and throughout the United States of America, its territories and all foreign countries, in and to the inventions described in said application, together with my entire right, title and interest in and to said application and such Letters Patent as may issue thereon or claim priority under international convention, including but not limited to continuations, divisionals, reissues, and reexaminations of said application of such Letters Patent; said inventions, applications and Letters Patent to be held and enjoyed by said ASSIGNEE for its own use and behalf and for its successors, assigns and legal representatives, to the full end of the term for which said Letters Patent may be granted as fully and entirely as the same would have been held by me had this assignment and sale not been made; I hereby convey all of my rights arising under or pursuant to any and all international agreements, treaties or laws relating to the protection of industrial property by filing any such applications for Letters Patent. I hereby acknowledge that this assignment, being of my entire right, title and interest in and to said invention, carries with it the right in ASSIGNEE to apply for and obtain from competent authorities in all countries of the world any and all Letters Patent by attorneys and agents of ASSIGNEE's selection and the right to procure the grant of all Letters Patent to ASSIGNEE for its own name as assignee of my entire right, title and interest therein.

AND, I hereby further agree for myself and my executors and administrators to execute upon request any other lawful documents and likewise to perform any other lawful acts which may be deemed necessary to secure fully the aforesaid invention to said ASSIGNEE, its successors, assigns, and legal representatives, but at its or their expense and charges, including: the execution of applications for patents in foreign countries; the execution of substitution, reissue, divisional or continuation applications; and preliminary or other statements or the giving of testimony in any interference or other proceeding in which said invention or any application or patent directed thereto may be involved; and I further hereby authorize ASSIGNEE or its attorneys or agents to insert the correct serial number and filing date into this assignment if none is indicated on that date of my execution of this assignment;

AND, I do hereby authorize and request the Commissioner of Patents of the United States to issue such Letters Patent as shall be granted upon said application or applications based thereon to said ASSIGNEE, its successors, assigns, and legal representatives.

IN TESTIMONY WHEREOF, I have hereunto set my hand and affixed my seal the date set forth below.

Inventor: _____
Joseph Jacobson

Dated: 6/7/99

Commonwealth of Massachusetts)
County of Middlesex) ss

Subscribed and sworn to before me, by the above-named Joseph Jacobson this 7th day of June, 1999.

_____
Notary Public
My Commission Expires: NOV. 25, 2005

574JBM2108/13.A768929-1

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
ASSISTANT SECRETARY AND COMMISSIONER
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JUNE 10, 1999

PTAS

TESTA, HURWITZ & THIBEAULT, LLP
JOSEPH B. MILSTEIN
HIGH STREET TOWER
125 HIGH STREET
BOSTON, MA 02110

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NUMBER OF PAGES: 4

BRIEF: ASSIGNMENT OF ASSIGNOR''S INTEREST (SEE DOCUMENT FOR DETAILS).

ASSIGNOR:
ALBERT, JOHNATHAN D.

DOC DATE: 02/08/1999

ASSIGNOR:
COMISKEY, BARRETT

DOC DATE: 02/08/1999

ASSIGNEE:
E INK CORPORATION
45 SPINELLI PLACE
CAMBRIDGE, MASSACHUSETTS 02138

SERIAL NUMBER: 09140862
PATENT NUMBER:

FILING DATE: 08/27/1998
ISSUE DATE:

MARCUS KIRK, EXAMINER
ASSIGNMENT DIVISION
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03-31-1999

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		Execution Date (Month Day Year)
Name	Johnathan D. Albert	2/8/99
Name	Barrett Comiskey	2/8/99
Name		/ /
Name		/ /
Name		/ /

Receiving Party ☐ Mark if additional names of receiving parties attached

Name (line 1): E Ink Corporation

Name (line 2):

Address (line 1): 45 Spinelli Place

Address (line 2):

Address (line 3): Cambridge (City) MA (State/Country) 02138 (Zip Code)

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Page 2 RECEIVED PATENT

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Area Code and Telephone Number

Name: Patent Administrator

Address (line 1): Testa, Hurwitz & Thibeault, LLP

Address (line 2): High Street Tower

Address (line 3): 125 High Street

Address (line 4): Boston, MA 02110

Pages Enter the total number of pages of the attached conveyance document including any attachments. 2

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Patent Application Number(s)	Patent Number(s)
09/140,862	

Patent Cooperation Treaty (PCT)

Enter PCT application number only if a U.S. Application Number has not been assigned.

PCT PCT PCT

PCT PCT PCT

Number of Properties Enter the total number of properties involved. # 1

Fee Amount Fee Amount for Properties Listed (37 CFR 3.41): $ 40

Method of Payment: Enclosed ☒ Deposit Account ☐

Deposit Account

(Enter for payment by deposit account or if additional fees can be charged to the account)

Deposit Account Number # 20-0531

Authorization to charge additional fees: Yes ☐ No ☒

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To the best of my knowledge and belief, the foregoing information is true and correct and any attached copy is a true copy of the original document. Charges to deposit account are authorized, as indicated herein.

JOSEPH B. MILSTEIN
Name of Person Signing

Joseph B. Milstein
Signature

2/26/99
Date

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Name	Barrett Comiskey	2/8/99
Name		/ /
Name		/ /
Name		/ /

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Address (line 1): 45 Spinelli Place

Address (line 2):

Address (line 3): Cambridge (City) MA (State/Country) 02138 (Zip Code)

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Name: Patent Administrator

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Deposit Account

(Enter for payment by deposit account or if additional fees can be charged to the account)

Deposit Account Number # 20-0531

Authorization to charge additional fees: Yes ☐ No ☒

Statement and Signature

To the best of my knowledge and belief, the foregoing information is true and correct and any attached copy is a true copy of the original document. Charges to deposit account are authorized, as indicated herein.

JOSEPH B. MILSTEIN	Joseph B. Milstein	2/26/99
Name of Person Signing	Signature	Date

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Attorney Docket No.
INK-006
(2108/13)

ASSIGNMENT

WHEREAS, We, Jonathan D. Albert and Barrett Comiskey have invented one or more improvements in:

Color Electrophoretic Displays

described in an application (or provisional application) for Letters Patent of the United States:

☐ identified by Attorney Docket No. INK-006, and/or executed by us of even date herewith and about to be filed in the United States Patent Office;

☒ Serial No. 09/140,862 filed in the United States Patent Office on 08/27/98; and

WHEREAS, E Ink Corporation (hereinafter "ASSIGNEE"), a corporation organized and existing under the laws of the State of Delaware, and having a usual place of business at 45 Spinelli Place, Cambridge, MA 02138 desires to acquire an interest therein, in accordance with agreements duly entered into with us;

NOW, THEREFORE, to all whom it may concern be it known that for and in consideration of said agreements and of other good and valuable consideration, the receipt of which is hereby acknowledged, we have sold, assigned and transferred and by these presents do hereby sell, assign and transfer unto said ASSIGNEE, its successors, assigns, and legal representatives, our entire right, title and interest in and throughout the United States of America, its territories and all foreign countries, in and to the inventions described in said application, together with our entire right, title and interest in and to said application and such Letters Patent as may issue thereon or claim priority under international convention, including but not limited to continuations, divisionals, reissues, and reexaminations of said application of such Letters Patent; said inventions, applications and Letters Patent to be held and enjoyed by said ASSIGNEE for its own use and behalf and for its successors, assigns and legal representatives, to the full end of the term for which said Letters Patent may be granted as fully and entirely as the same would have been held by us had this assignment and sale not been made; we hereby convey all of our rights arising under or pursuant to any and all international agreements, treaties or laws relating to the protection of industrial property by filing any such applications for Letters Patent. We hereby acknowledge that this assignment, being of our entire right, title and interest in and to said inventions, carries with it the right in ASSIGNEE to apply for and obtain from competent authorities in all countries of the world any and all Letters Patent by attorneys and agents of ASSIGNEE's selection and the right to procure the grant of all Letters Patent to ASSIGNEE for its own name as assignee of our entire right, title and interest therein.

AND, we hereby further agree for ourselves and our executors and administrators to execute upon request any other lawful documents and likewise to perform any other lawful acts which may be deemed necessary to secure fully the aforesaid invention to said ASSIGNEE, its successors, assigns, and legal representatives, but at its or their expense and charges, including: the execution of applications for patents in foreign countries; the execution of substitution, reissue, divisional or continuation applications; and preliminary or other statements or the giving of testimony in any interference or other proceeding in which said inventions or any application or patent directed thereto may be involved; and

we further hereby authorize ASSIGNEE or its attorneys or agents to insert the correct serial number and filing date into this assignment, if none is indicated on that date of our execution of this assignment;

AND, we do hereby authorize and request the Commissioner of Patents of the United States to issue such Letters Patent as shall be granted upon said application or applications based thereon to said ASSIGNEE, its successors, assigns, and legal representatives.

IN TESTIMONY WHEREOF, we have hereunto set our hands and affixed our seals the date set forth below.

Inventor: _____
Jonathan D. Albert

Commonwealth of Massachusetts)
County of) ss

Subscribed and sworn to before me, by the above-named Jonathan D. Albert this 8th day of February, 1999.

_____
Notary Public: John D. Lanza
My Commission Expires: July 29, 2005

Inventor: _____
Barrett Comiskey

Commonwealth of Massachusetts)
County of) ss

Subscribed and sworn to before me, by the above-named Barrett Comiskey this 8th day of February, 1999.

_____
Notary Public: John D. Lanza
My Commission Expires: July 29, 2005

EXHIBIT B

organ of Cor·ti \-'kȯrt-ē\ [Alfonso *Corti* †1876 Ital. anatomist] (1882) : a complex epithelial structure in the cochlea that rests on the internal surface of the basilar membrane and in mammals is the chief part of the ear by which sound is directly perceived

or·gan-o-gen·e·sis \ˌȯr-gə-nō-'jen-ə-səs, ȯr-ˌgan-ə-\ *n* [NL] (ca. 1860) : the origin and development of bodily organs — compare MORPHOGENESIS — **or·gan-o-ge·net·ic** \-jə-'net-ik\ *adj* — **or·gan-o-ge·net·i·cal·ly** \-i-k(ə-)lē\ *adv*

or·gan-o-lep·tic \ˌȯr-gə-nō-'lep-tik, ȯr-ˌgan-ə-\ *adj* [F *organoleptique*, fr. *organ-* + Gk *lēptikos* disposed to take, fr. *lambanein* to take — more at LATCH] (1852) 1 : being, affecting, or relating to qualities (as taste, color, odor, and feel) of a substance (as a food or drug) that stimulate the sense organs 2 : involving use of the sense organs ⟨~ evaluation of foods⟩ — **or·gan-o-lep·ti·cal·ly** \-ti-k(ə-)lē\ *adv*

or·gan-ol·o·gy \ˌȯr-gə-'näl-ə-jē\ *n* [ISV] (ca. 1842) : the study of the organs of plants and animals

or·gano-mer·cu·ri·al \ȯr-ˌgan-ō-(ˌ)mər-'kyůr-ē-əl\ *n* (1938) : an organic compound or a pharmaceutical preparation containing mercury

or·gano-me·tal·lic \-mə-'tal-ik\ *adj* [ISV] (1852) : of, relating to, or being an organic compound that usu. contains a metal or metalloid bonded directly to carbon — **organometallic** *n*

or·ga·non \'ȯr-gə-ˌnän\ *n* [Gk, lit., tool — more at ORGAN] (1543) : an instrument for acquiring knowledge: *specif* : a body of principles of scientific or philosophic investigation

or·gano-phos·phate \ȯr-ˌgan-ə-'fäs-ˌfāt\ *n* (1949) : an organophosphorus pesticide — **organophosphate** *adj*

or·gano-phos-pho·rus \-ˌfäs-'fōr-əs, -'fȯr-\ *adj* (1950) : of, relating to, or being a phosphorus-containing organic pesticide (as malathion) that acts by inhibiting cholinesterase — **organophosphorus** *n*

organ–pipe cactus *n* (1908) : any of several tall upright cacti of the southwestern U.S. and adjacent Mexico: as **a** : SAGUARO **b** : a cactus (*Lemnaireocereus marginatus* or *Pachycereus marginatus*) that branches at the base to form several ridged upright stems and bears 2-inch red and greenish white flowers

or·ga·num \'ȯr-gə-nəm\ *n* [ML, fr. L, organ] (1614) 1 : ORGANON 2 : early polyphony of the late Middle Ages that consists of one or more voice parts accompanying the cantus firmus in parallel motion usu. at a fourth, fifth, or octave above or below; *also* : a composition in this style

or·gan·za \ȯr-'gan-zə\ *n* [prob. alter. of *Lorganza*, a trademark] (1820) : a sheer dress fabric resembling organdy and usu. made of silk, rayon, or nylon

or·gan·zine \'ȯr-gən-ˌzēn\ *n* [F or It; F *organsin*, fr. It *organzino*] (1699) : a raw silk yarn used for warp threads in fine fabrics

or·gasm \'ȯr-ˌgaz-əm\ *n* [NL *orgasmus*, fr. Gk *orgasmos*, fr. *organ* to grow ripe, be lustful; akin to Skt *ūrjā* sap, strength] (1763) : intense or paroxysmal emotional excitement; *esp* : the climax of sexual excitement typically occurring toward the end of coitus — **or·gas·mic** \ȯr-'gaz-mik\ *also* **or·gas·tic** \-'gas-tik\ *adj*

or·geat \'ȯ(ə)r-ˌzhä(t)\ *n* [F, fr. MF, fr. *orge* barley, fr. L *hordeum*; akin to OHG *gersta* barley, Gk *kri*] (1754) : a sweet almond-flavored nonalcoholic syrup used as a cocktail ingredient or food flavoring

or·gi·as·tic \ˌȯr-jē-'as-tik\ *adj* [Gk *orgiastikos*, fr. *orgiazein* to celebrate orgies, fr. *orgia*] (1698) 1 : of, relating to, or marked by orgies 2 : characterized by unrestrained emotion — **or·gi·as·ti·cal·ly** \-ti-k(ə-)lē\ *adv*

or·gone \'ȯ(ə)r-ˌgōn\ *n* [prob. fr. orgasm + *-one* (as in *hormone*)] (1942) : a vital energy held to pervade nature and to be made available for use by the human body by sitting in a specially designed box

or·gu·lous \'ȯr-g(y)ə-ləs\ *adj* [ME, fr. OF *orgueilleus*, fr. *orgueil* pride, of Gmc origin; akin to OHG *urguol* distinguished] (13c) : PROUD

or·gy \'ȯr-jē\ *n, pl* **orgies** [MF *orgie*, fr. L *orgia*, pl., fr. Gk; akin to Gk *ergon* work — more at WORK] (1589) 1 : secret ceremonial rites held in honor of an ancient Greek or Roman deity and usu. characterized by ecstatic singing and dancing 2 **a** : drunken revelry **b** : an excessive sexual indulgence (as at a wild party) 3 : something that resembles an orgy in lack of control or moderation ⟨soldiers engaging in an ~ of destruction⟩

-oria *pl of* -ORIUM

-o·ri·al \'ȯr-ē-əl, 'ōr-\ *adj suffix* [ME, fr. L *-orius* -ory + ME *-al*] : of, belonging to, or connected with ⟨combinat*orial*⟩

orib·a·tid \ȯ-'rib-ət-əd, ˌȯr-ə-'bat-əd\ *n* [NL *Oribatidae* (coextensive with *Oribatoidea*), fr. *Oribata*, genus name, fr. Gk *oribatēs* walking the mountains, fr. *oros* mountain + *-batēs*, fr *bainein* to go — more at RISE, COME] (1948) : any of a superfamily (Oribatoidea) of small oval eyeless nonparasitic mites having a heavily sclerotized integument with a leathery appearance — **oribatid** *adj*

ori·el \'ȯr-ē-əl, 'ōr-\ *n* [ME, porch, oriel, fr. MF *oriol* porch] (14c) : a large bay window projecting from a wall and supported by a corbel or bracket

¹ori·ent \'ȯr-ē-ənt, 'ōr-, -ē-ˌent\ *n* [ME, fr. MF, fr. L *orient-*, *oriens*, fr. prp. of *oriri* to rise — more at RISE] (14c) 1 *archaic* : EAST 1b 2 *cap* : EAST 2 3 **a** : a pearl of great luster **b** : the luster or sheen of a pearl

²orient *adj* (15c) 1 *archaic* : ORIENTAL 1 2 **a** : LUSTROUS, SPARKLING ⟨~ gems⟩ **b** *archaic* : RADIANT, GLOWING 3 *archaic* : rising in the sky

³ori·ent \'ȯr-ē-ˌent, 'ōr-\ *vt* [F *orienter*, fr. MF, fr. *orient*] (1727) 1 **a** : to cause to face or point toward the east: *specif* : to build (a church or temple) with the longitudinal axis pointing eastward and the chief altar at the eastern end **b** : to set or arrange in any determinate position esp. in relation to the points of the compass **c** : to ascertain the bearings of 2 **a** : to set right by adjusting to facts or principles **b** : to acquaint with the existing situation or environment 3 : to cause the axes of the molecules of to assume the same direction

ori·en·tal \ˌȯr-ē-'ent-ᵊl, ˌōr-\ *adj* (14c) 1 *often cap* : of, relating to, or situated in the Orient 2 **a** : of superior grade, luster, or value **b** : being corundum or sapphire but simulating another gem in color 3 *often cap* : of, relating to, or having the characteristics of Orientals 4 *cap* : of, relating to, or constituting the biogeographic region that includes Asia south and southeast of the Himalayas and the Malay archipelago west of Wallace's line — **ori·en·tal·ly** \-ᵊl-ē\ *adv*

Oriental *n* (15c) : a member of one of the indigenous peoples of the Orient

oriental fruit moth *n* (1921) : a small nearly cosmopolitan moth (*Grapolitha molesta*) prob. of Japanese origin whose larva is injurious to the twigs and fruit of orchard trees and esp. the peach — called also *oriental peach moth*

ori·en·tal·ism \ˌȯr-ē-'ent-ᵊl-ˌiz-əm\ *n, often cap* (1769) 1 : a trait, custom, or habit of expression characteristic of oriental peoples 2 : scholarship or learning in oriental subjects — **ori·en·tal·ist** \-ᵊl-əst\ *n, often cap*

ori·en·tal·ize \-ᵊl-ˌīz\ *vb* **-ized; -iz·ing** *vt, often cap* (1823) : to make oriental ~ *vi, often cap* : to become oriental

Oriental poppy *n* (1731) : an Asian perennial poppy (*Papaver orientale*) that is commonly cultivated for its large showy flowers

Oriental rug *n* (1881) : a handwoven or hand-knotted one-piece rug or carpet made in the Orient — called also *Oriental carpet*

ori·en·tate \'ȯr-ē-ən-ˌtāt, 'ōr-, -ˌen-\ *vb* **-tat·ed; -tat·ing** *vt* (1849) : ORIENT ~ *vi* : to face or turn to the east

ori·en·ta·tion \ˌȯr-ē-ən-'tā-shən, ˌōr-, -ˌen-\ *n* (1849) 1 **a** : the act or process of orienting or of being oriented **b** : the state of being oriented; *broadly* : ARRANGEMENT, ALIGNMENT 2 : a usu. general or basic sense of direction of thought, inclination, or interest 3 : change of position by organs, organelles, or organisms in response to external stimulus

ori·en·ta·tion·al \-shnəl, -shən-ᵊl\ *adj* — **ori·en·ta·tion·al·ly** \-ē\ *adv*

ori·ent·ed \'ōr-ē-ˌent-əd, 'ōr-\ *adj* (1944) : intellectually or emotionally directed ⟨humanistically ~ scholars⟩

ori·en·teer·ing \ˌōr-ē-ən-'ti(ə)r-iŋ, ˌōr-, -ˌen-\ *n* [modif. (influenced by *-eer*) of Sw *orientering*, fr. *orientera* to orient] (1948) : a cross-country race in which each participant uses a map and compass to navigate his own way between checkpoints along an unfamiliar course

or·i·fice \'ȯr-ə-fəs, 'ar-\ *n* [ME, fr. MF, fr. LL *orificium*, fr. L *os* mouth — more at ORAL] (15c) : an opening (as a vent, mouth, or hole) through which something may pass — **or·i·fi·cial** \ˌȯr-ə-'fish-əl\ *adj*

ori·flamme \'ōr-ə-ˌflam, 'ar-\ *n* [ME *oriflamble*, the banner of St Denis, fr. MF, fr. ML *aurea flamma*, lit., golden flame] (1600) : a banner as a symbol, or ideal inspiring devotion or courage

ori·ga·mi \ˌōr-ə-'gäm-ē\ *n* [Jp, folded paper, fr. *ori* folding] (1956) : the art or process of Japanese paper folding

orig·a·num \ə-'rig-ə-nəm\ *n* [ME, fr. L, wild marjoram, fr. Gk *origanon*] (12c) : any of various fragrant aromatic plants of the mint or verbena families used as seasonings; *esp* : OREGANO 1

or·i·gin \'ōr-ə-jən, 'ar-\ *n* [ME *origine*, prob. fr. MF, fr. L *origin-*, *origo*, fr. *oriri* to rise — more at RISE] (15c) 1 : ANCESTRY, PARENTAGE 2 **a** : rise, beginning, or derivation from a source **b** : the point at which something begins or rises or from which it derives ⟨the ~ of the custom is lost in the mist of time⟩; *also* : something that creates, causes, or gives rise to another ⟨this spring is the ~ of the brook⟩ 3 : the more fixed, central, or larger attachment of a muscle 4 : the intersection of coordinate axes

syn ORIGIN, SOURCE, INCEPTION, ROOT mean the point at which something begins its course or existence. ORIGIN applies to the things or persons from which something is ultimately derived and often to the causes operating before the thing itself comes into being; SOURCE applies more often to the point where something springs into being; INCEPTION stresses the beginning of something without implying causes; ROOT suggests a first, ultimate, or fundamental source not easily discerned.

¹orig·i·nal \ə-'rij-ən-ᵊl, -'rij-nəl\ *n* (14c) 1 *archaic* : the source or origin from which something arises: *specif* : ORIGINATOR 2 **a** : that from which a copy, reproduction, or translation is made **b** : a work of art composed firsthand 3 **a** : a person of fresh initiative or inventive capacity **b** : an eccentric person

²original *adj* (14c) 1 : of, relating to, or constituting an origin or beginning : INITIAL ⟨the ~ part of the house⟩ 2 **a** : not secondary, derivative, or imitative **b** : being the first instance or source from which a copy, reproduction, or translation is or can be made 3 : independent and creative in thought or action : INVENTIVE *syn* see NEW — **original·ly** \-ē\ *adv*

orig·i·nal·i·ty \ə-ˌrij-ə-'nal-ət-ē\ *n* (1742) 1 : the quality or state of being original 2 : freshness of aspect, design, or style 3 : the power of independent thought or constructive imagination

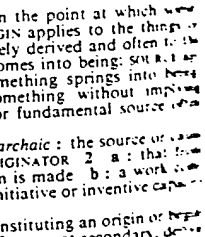
original sin *n* (14c) : the state of sin that according to Christian theology characterizes all human beings as a result of Adam's fall

orig·i·nate \ə-'rij-ə-ˌnāt\ *vb* **-nat·ed; -nat·ing** *vt* (1657) : to give rise to : INITIATE ~ *vi* : to take or have origin : BEGIN *syn* see SPRING

orig·i·na·tion \-ˌrij-ə-'nā-shən\ *n* — **orig·i·na·tor** \-'rij-ə-ˌnāt-ər\ *n*

orig·i·na·tive \ə-'rij-ə-ˌnāt-iv, -nət-\ *adj* (1827) : having ability to originate : CREATIVE — **orig·i·na·tive·ly** *adv*

O–ring \'ō-ˌriŋ\ *n* (1946) : a ring (as of synthetic rubber) used as a gasket



oriole 2

ori·ole \'ōr-ē-ˌōl, 'ōr-, -ē-əl\ *n* [F *oriol*, fr. L *aureolus*, dim. of *aureus* golden, fr. *aurum* gold; akin to Lith *auksas* gold] (1776) 1 : any of a family (Oriolidae) of usu. brightly colored Old World passerine birds related to the crows 2 : any of a family (Icteridae) of New World passerine birds of which the males are usu. bright black and yellow or orange and the females are chiefly greenish or yellowish

Ori·on \ə-'rī-ən, ō-\ *n* [L, fr. Gk *Ōriōn*] 1 : a giant hunter slain by Artemis in Greek mythology 2 [L (gen. *Orionis*)] : a constellation on the equator east of Taurus represented on charts by the figure of a hunter with belt and sword

or·is·mol·o·gy \ˌōr-əz-'mäl-ə-jē, ˌar-\ *n* [Gk *horismos* definition (fr. *horizein* to define) — E *-logy*] (1816) : the science of defining technical terms : TERMINOLOGY — **or·is·mo·log·i·cal** \ˌōr-əz-mə-'läj-i-kəl, ˌar-\ *adj*

or·i·son \'ōr-ə-sən, 'ar-, -zən\ *n* [ME, fr. OF, fr. LL *orationem*, *oratio*] (12c) : PRAYER

-o·ri·um \'ōr-ē-əm, 'ōr-\ *n suffix, pl* **-oriums** *or* **-o·ria** \-ē-ə\ [L *-orium*, *-torium*] : -ORY (*haustorium*)

A
B

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EXHIBIT C

practice guide

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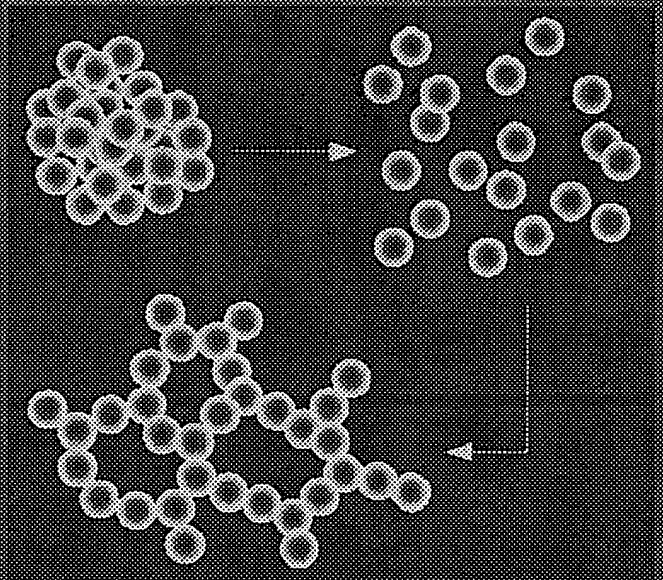
The Use of Nomenclature in Dispersion Science and Technology



Vincent A. Hackley
Chiara F. Ferraris

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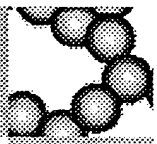
NIST Recommended Practice Guide



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The Use of Nomenclature in Dispersion Science and Technology

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Karen H. Brown, Acting Director

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Foreword

Measurements and standards are universally recognized as playing an integral role in the manufacturing process. They enhance reliability by providing a basis for quantifying and comparing material properties during each phase of manufacturing, from raw materials to the finished product. Equally important is the establishment of a uniform and widely accepted nomenclature for describing experimental methods and instrumentation, for sharing technical ideas and concepts and to provide a sound basis on which to standardize measurement methods and data reporting practices. This is especially true in the ceramics community, due to its cross-disciplinary nature and due to the utilization of ceramic powders throughout numerous industries.

Ceramic suspensions, gels and pastes (i.e., dispersions) are the starting materials for a wide variety of applications, playing critical roles in the processing of products ranging from whitewares, pigments, paper, and cement for the construction industry to multilayer ceramic packages and chemical mechanical planarization slurries for the microelectronics industry. Unfortunately, researchers and engineers working in these diverse fields often speak different languages. Even within the same field, variations in terminology are common. The need for broadly accepted, uniform and precise nomenclature was acknowledged recently by the Ceramic Processing Characterization Consortium (CPCC), a voluntary cooperative organization with participants representing industry, instrument companies, academia and government. A principal goal of the consortium was to develop guidelines and recommended practices for the implementation of process measurements. CPCC members identified nomenclature as a high priority issue in the areas of dispersion and dispersion rheology. As a result, work was initiated on two nomenclature guides, which were ultimately distributed as NIST Special Publications 945 and 946.

The present document is essentially a compilation, with updates, of these two previous publications, and provides guidelines for the use of technical and scientific nomenclature relevant to ceramic dispersions.

1. INTRODUCTION

The use of nomenclature for describing dispersed particulate systems, along with their associated properties and components, is often inconsistent and subject to misinterpretation in the technical and scientific literature. For example, terms for describing the state of association of particles in suspension (e.g., *aggregate* or *agglomerate*) often carry specific connotations that vary among different authors. This guide has been prepared as a resource for researchers, engineers and students working in dispersion-based applications. In compiling this guide, we drew on a number of resources, including books, review articles and published terminologies. To the extent possible, every effort was made to maintain a degree of uniformity with existing standards and conventions, including published terminologies from the American Concrete Institute (ACI), the British Standards Institute (BSI), the International Union of Pure and Applied Chemistry (IUPAC) and the Society of Rheology, as well as current and draft ASTM and ISO standards.

We intend this guide to serve as a resource for practitioners working in various fields in which ceramic dispersions are used, where *ceramic* is broadly defined as a non-metallic inorganic material. Equations have been used sparingly, and only where necessary for clarity or where they are integral to the subject at hand. This is not, nor is it intended to be, an exhaustive compilation. Rather, this document focuses on commonly encountered terms, and endeavors to provide a consistent framework for improved technical communication.

The technical nomenclature portion of this guide is divided into two sections. The first section is derived from Special Publication 945, and deals with general topics related to dispersion science and technology, such as particle agglomeration and colloidal stability. The second section is based on Special Publication 946, and provides definitions of terms and expressions relating to the measurement of rheological properties in liquid-based ceramic dispersions (i.e., suspensions, pastes and gels).

In addition to the glossaries of basic terms, the guide is organized so that the reader can more readily locate related terms associated with specific subject areas. Defined terms are indicated in boldface type. Where alternative or equivalent terms exist, they are shown in brackets adjacent to the preferred term. Terms used in definitions, and which are defined separately in the guide, are indicated in italic at their first appearance in that paragraph or section. The only exception to this rule is the term viscosity in Part II, which is not italicized when it appears by itself, due to its ubiquity throughout the text.

Descriptions of instrumentation provided in this guide are generic in nature, and are presented solely for the purpose of identifying key measurement techniques and their associated nomenclature.

2. NOMENCLATURE FOR DISPERSION TECHNOLOGY

2.1 Physical Description of Dispersed Systems

2.1.1 Primary Terms

aerosol
Droplets or *particles* dispersed in a gaseous phase.

continuous phase
Constituting the medium, a phase that exhibits continuity throughout the dispersion; e.g., the liquid in a *suspension.*

dispersed phase [discontinuous phase]
In a *dispersion*, the phase that is distributed in the form of discrete discontinuities (*particles*, *droplets* or bubbles), in a second immiscible phase that is continuous.

dispersion
In general, a two-phase system in which discontinuities of any kind (solid, liquid, gas) are dispersed in a *continuous phase* of a different composition or state; more specifically in the field of ceramics, the term dispersion is used to describe a *suspension* of solid *particles* in a liquid medium.

emulsion
A *dispersion* consisting of two or more liquid phases.

hydrosol
A *sol* in which water forms the *dispersion* medium.

liquid phase
Consisting of a condensed fluid; e.g., the *dispersion* medium in a *suspension.*

organosol
A *sol* in which an organic liquid forms the *dispersion* medium.

particulate phase [solid phase]
The particles in a *suspension*, *gel* or *aerosol.*

slip
A term that refers to a *suspension* prepared for the expressed purpose of consolidating the *solid phase* (e.g., by slip-casting, tape-casting or spray drying).

slurry
A concentrated ceramic particulate *suspension*.

sol
A liquid *dispersion* containing particles of *colloidal* dimensions.

suspension
A liquid in which solid particles are dispersed.

2.1.2 Related Terms

heterodisperse
Describes a *polydisperse* particulate system in which more than one discrete size distribution mode occurs; e.g., bimodal, trimodal, etc.

monodisperse
Realistically, all *dispersions* exhibit a finite spread in their *particle* size distribution. In practice, the term monodisperse can be used to identify a dispersed system in which all particles are of nearly the same size, forming a narrow (unimodal) distribution about an average value. Numerically, a dispersion may be considered monodisperse if 90 % of the distribution (1.645 σ, where σ is the standard deviation of the size distribution) lies within ±5 % of the average size, $\langle d \rangle$:

$$\frac{1.645\,\sigma}{\langle \mathbf{d} \rangle} \leq 0.05$$

polydisperse
Describes a dispersed system in which many *particle* sizes occur. In practice, a system may be considered polydisperse if less than 90 % of the size distribution (1.645 σ, where σ is the standard deviation of the size distribution) lies within ±5 % of the average size, $\langle d \rangle$:

$$\frac{1.645\,\sigma}{\langle \mathbf{d} \rangle} > 0.05$$

well-dispersed
A term used to describe a *stable suspension* in which the *minimum particle size* has been achieved.

2.1.3 Recommendations

relative concentration terms
It is recommended that relative descriptive terms relating to particle concentration in *suspension* (e.g., dilute or concentrated) be defined in such a manner that the reader has a clear understanding of their relevance to the measurement or application at hand. For instance, in a light scattering measurement, "dilute" may infer the absence of multiple scattering, whereas in an ultrasonic measurement this term may imply a linear response with concentration. These conditions may vary by several orders of magnitude with respect to particle concentration. Concentration can also by defined on a more fundamental basis, taking into consideration the relative dominance of thermal, hydrodynamic, or surface forces in controlling suspension properties.

2.2 States of Subdivision (Dispersed Phase)

2.2.1 Definitions Based on Size

nanosize [nanophase]
A special state of subdivision implying that the *particles* (or atomic clusters) have average dimensions smaller than roughly 100 nm, and exhibit properties not normally associated with the bulk phase (e.g., quantum optical effects).

colloid
State of subdivision implying that the *particles* have at least in one direction a dimension roughly between 1 nm and 1 μm. Colloids are significantly affected by *Brownian motion* when suspended in a liquid.

ultrafine
State of subdivision implying that the *particles* have in any given direction a maximum dimension lying roughly between 1 μm and 10 μm.

fine [subsieve range]
State of subdivision implying that the *particles* have in any given direction a maximum dimension less than roughly 37 μm.

coarse [sieve range]
State of subdivision implying that the *particles* have in at least one direction a dimension greater than roughly 37 μm.

granule
State of subdivision generally referring to dry particulates with dimensions lying roughly in the 50 μm to 200 μm range; typically, granules are *aggregates* of finer particles produced by spray-drying. Granulation is performed for ease of handling during subsequent consolidation operations.

2.2.2 Definitions Based on Structure

particle
Any condensed-phase tridimensional discontinuity in a dispersed system may generally be considered a particle; e.g., *droplets* in an *emulsion* or solids dispersed in a liquid. The term is normally used in reference to solid materials. An *aggregate* may also be regarded as a particle.

droplet
Liquid-phase *particle* in an *emulsion* or *aerosol.*

particulate
Composed of distinct *particles*.

primary particle
Smallest identifiable subdivision in a *particulate* system. Primary particles may also be subunits of *aggregates*.

microsphere
Refers to a spherical *particle* in the micrometer size range.

aggregate
A cohesive mass consisting of *particulate* subunits.

hard-aggregate
An *aggregate* that cannot be easily redispersed by the application of moderate mechanical agitation (shaking, stirring, or ultrasonication) and/or mild chemical treatment. Hard-aggregates consist of subunits that have been chemically bonded or *fused.*

agglomerate
In a *suspension*, an *aggregate* held together by physical or electrostatic forces.

coagulate [coagulum]
In a *suspension*, an *aggregate* formed by the addition of electrolyte.

floc
In a *suspension*, an *aggregate* formed by the addition of a polymer. Flocs are generally characterized by a loose structure (low density).

powder
A relatively dry, undispersed accumulation of *particulate* matter with a macroscopic consistency.

gel
Bicontinuous structure with a solid and a liquid component. The solid network may consist of *particles* or polymers, held together by covalent, ionic or dispersion (physical) forces. The network may be elastic, viscoelastic or plastic. The scale of the mesh of the network (distance between cross links) is of *colloidal* dimensions.

aerogel
A porous solid produced from a *gel* in such a way that very little shrinkage occurs. Typically, the term refers to materials made by supercritical extraction of the solvent, although structurally equivalent materials can be made under ambient conditions by increasing network stiffness and/or elastic recovery, and by reducing interfacial tension.

alcogel
A *gel* containing an alcoholic liquid phase.

hydrogel
A *gel* containing an aqueous liquid phase.

xerogel
Porous solid made by drying a *gel* under subcritical conditions.

2.2.3 Related Terms

average agglomeration number (AAN)
An estimate of the degree of *agglomeration* in a *suspension*. AAN is the average number of *primary particles* contained within an *agglomerate*. AAN is calculated from the ratio of the median particle size, as determined by, for example, light scattering, *sedimentation* or electrical zone sensing techniques,

to the average equivalent spherical volume (V_{BET}) given by the BET gas adsorption method, such that:

$$AAN = \frac{V_{50}}{V_{BET}} = \left(\frac{D_{50} \cdot SSA \cdot \rho}{6}\right)^3$$

where V_{50} is the equivalent spherical volume calculated from the median diameter, D_{50} in μm, SSA is the specific surface area in m^2/g and ρ is the particle density in g/cm^3.

equivalent spherical diameter
The diameter of a sedimenting particle determined from Stokes' law and assuming a spherical shape. The term is sometimes used in conjunction with other measurement techniques and theoretical constructs, where spherical geometry is assumed.

fractal
A structure that has an irregular geometry under all scales of observation (i.e., it is non-Euclidian). The fractal dimension of a species, D_f, is the exponent to which a characteristic length scale must be raised to obtain proportionality with the overall size of the species. Destabilized suspensions tend to form aggregates with fractal structures. In this case, D_f has a value lying between 1 and 3, where D_f=3 is a fully dense object.

minimum particle size (MPS)
An experimental quantity operationally defined as the minimum *particle* size that can be achieved by a particular *dispersion* process as determined by an appropriate measurement technique. The characteristic dimension used in determining the MPS should be clearly noted (e.g., mean size, median size, modal size, etc.).

ultimate working unit
An individual *particle* or group of particles that retains its structure throughout a *dispersion* process and subsequent application. See also *minimum particle size*.

2.2.4 Recommendations

floccule
It is recommended that this term not be used in the ceramic literature. (see *floc*)

hard, soft
With the exception of the defined term *hard-aggregate*, it is recommended that such adjectives be avoided in the context of dispersed phase structure. If their use is deemed necessary to convey material-specific information, then the author should make a clear statement that defines the meaning and extent of usage.

2.3 Association and Dissociation Processes

2.3.1 Association Processes

aggregation
A general term defined as any process by which particles collect to form a cohesive mass or cluster; the resulting structure is called an *aggregate.*

agglomeration
Formation of *aggregates* in a *suspension* through physical (van der Waals, hydrophobic) or electrostatic forces. The resulting structure is called an *agglomerate.*

coagulation
A specific type of *agglomeration* in which formation of *aggregates* is induced by the addition of electrolyte to a *suspension.* The resulting structure is termed the *coagulate* or *coagulum*, while the electrolyte additive is termed the *coagulant.*

flocculation
Formation of *aggregates* in a *suspension* mediated by polymeric species, that are either attached to the particles or exist freely in the suspending medium. The resulting structure is called a *floc*, while the polymer additive is termed a *flocculant.* Polymer bridging is a flocculation process.

gelation
Formation of a continuous (space-filling) solid network characterized by a finite static shear modulus (stress/strain ratio); results from percolation of bonds between *particles* or polymers. The resulting structure is termed a *gel.*

fusion
Process by which *particles* form irreversibly bonded structures; often characterized by the appearance of interparticle necks. (see also *hard-aggregates*)

heteroagglomeration, heterocoagulation, heteroflocculation
Generally refers to the *aggregation* of dissimilar particles; in ceramic applications, the formation of *aggregates* by the cohesion between *particles* of different materials (e.g., alumina and silica).

orthokinetic aggregation
The process of aggregation induced by hydrodynamic motions, such as stirring, *sedimentation* or convection.

perikinetic aggregation
The process of *aggregation* induced by *Brownian motion.*

sol-gel
Process for making a *gel* from *colloidal* or molecular precursors.

2.3.2 Dissociation Processes

deagglomeration
Reversal of *agglomeration*, i.e., the *dispersion* of *agglomerates* to form a *suspension.*

deflocculation
Reversal of *flocculation*, i.e., the *dispersion* of *flocs* to form a *suspension.*

comminution
Breaking down large pieces to the required size; term commonly used in association with milling of ceramic *slurries.*

peptization
Refers to the reversal of *agglomeration* by the addition of a strong acid or strong base, such as HCl or NaOH.

2.3.3 Related Terms

diffusion-limited rate
Refers to a rate of *aggregation* corresponding to the frequency of encounter (collision rate) of the *particles.* Each collision results in particle adherence (i.e., a sticking probability equal to 1). The rate of encounter is controlled by the diffusion rate, which depends on the viscosity of the medium, the dimensions of the particles, and the concentration of the particles.

reaction-limited rate
Refers to a rate of *aggregation* that is controlled by the reactivity of the *particles* (i.e., the frequency of collisions resulting in particle sticking). Usually characterized by a sticking probability much less than 1. A low sticking probability results from the presence of an energy barrier.

syneresis
Spontaneous shrinking of a *gel* with exudation of liquid.

ultrasonication
Application of high-energy, high-frequency sound to a *suspension* in order to disperse *aggregates*. Dispersion is thought to arise from the energy released during fluid cavitation.

2.3.4 Recommendations

sonication, sonification
It is recommended that these terms not be used in the ceramic literature. (see *ultrasonication*)

2.4 Dispersion Stability

2.4.1 States of Stability

colloidal stability
A physical state that characterizes the relative ability of *colloids* to remain dispersed in a liquid; *suspensions* that do not *aggregate* at a significant rate are said to be colloidally stable. The precise connotation depends on the time frame under consideration. Colloidal stability is a form of *kinetic stability*, and is therefore considered a metastable thermodynamic state. From this perspective, *aggregation* may be described as a transition from a metastable to a stable state, occurring at rates that depend on the magnitude of the activation energy barrier that separates them.

kinetic stability
Most dispersed systems are thermodynamically unstable, relative to their separate bulk phases; however, a dispersion may exist for an appreciable length of time and therefore exhibit kinetic stability. The term may be used in reference to various destabilizing processes, e.g., *aggregation*, coalescence or *sedimentation*.

stable suspension
A *suspension* that has sufficient *kinetic stability* to prevent the occurrence of significant *aggregation* as measured over a relevant time frame. Stability may be ascertained by suitable experimental means, such as *particle* size, turbidity or *sedimentation* measurements.

unstable suspension
A *suspension* that lacks *kinetic stability* as measured over a relevant time frame; a highly unstable *suspension* is one that is subject to rapid (*diffusion-limited*) *aggregation.*

2.4.2 Stability Mechanisms

electrostatic stabilization
Mechanism in which *aggregation* is inhibited by the presence of a mutually repulsive electrostatic potential that surrounds each *particle.*

steric stabilization
Mechanism in which *aggregation* is inhibited by the presence of an adsorbed polymer layer that is firmly anchored to the *particle* surface so as not to desorb during collisions. In general, a *steric stabilizing* agent has one portion of its structure that exhibits low solubility in the *dispersion* medium and/or high affinity for the *particle* surface, and the other portion is soluble in the medium.

electrosteric stabilization
Mechanism in which *aggregation* is inhibited by the combined effects of *electrostatic* and *steric stabilization*. Usually associated with the *adsorption of polyelectrolytes* onto the *particle* surface.

depletion stabilization
Mechanism in which *aggregation* is inhibited by the presence of free (non-adsorbed) polymer due to the creation of high-energy depletion zones (i.e., depleted of polymer compared to the bulk solution) between closely interacting *particle* surfaces.

2.4.3 Interaction Terms

DLVO
An abbreviation for a theory of the stability of *colloidal dispersions* describing the pair-wise interaction between charged *particles* in a dielectric medium. The

theory, derived independently by Derjaguin and Landau, and by Verwey and Overbeek, calculates the opposing effects of attractive van der Waals forces and repulsive electrostatic forces on the *interaction potential.*

interaction potential
The potential free energy between two surfaces, typically presented as a function of separation distance. By convention, a positive potential is mutually repulsive and a negative potential is mutually attractive.

primary maximum
The first appearance of a maximum in the *interaction potential energy* curve with increasing separation distance. The primary maximum results from the fact that repulsive and attractive forces decay at different rates as a function of separation distance. In *DLVO* theory, a large primary maximum acts as an energy barrier, preventing *aggregation* of *particles* into the *primary minimum.*

primary minimum
The first appearance of a minimum in the *interaction potential* curve with increasing separation distance. The primary minimum results from the fact that repulsive and attractive forces decay at different rates as a function of separation distance. In *DLVO* theory, a deep (negative) primary minimum acts as an energy well, allowing *particles* to adhere and resulting in a loss of *colloidal stability.*

secondary minimum
A shallow energy minimum (usually of the order of a few *kT*) in the *interaction potential* curve occurring at relatively large separation distances beyond that of the *primary maximum.* In the presence of such an energy well, secondary minimum *aggregation* may occur. Because of the shallow nature of the secondary minimum, the *aggregates* formed are held together weakly and as such tend to be unstable toward rather small energy inputs such as stirring.

Born repulsion [hard core repulsion]
As two surfaces are brought into close contact, the attractive van der Waals force between them increases continuously. At some point in their approach, the electron clouds of the two surfaces begin to overlap, giving rise to a repulsive force termed the Born or hard core repulsion. This results in a steep increase in the *interaction potential* curve at very small interatomic separation distances, becoming effectively infinite when interpenetration occurs.

solvation [structural] forces
Non-*DLVO* forces that occur at extremely small separation distances (typically

a few molecular diameters) when *particles* interact through an intervening fluid medium. These forces arise whenever liquid molecules are induced to order into quasi-discrete layers between surfaces, and can result in a monotonically increasing (repulsive), monotonically decreasing (attractive) or oscillatory *interaction potential*. In aqueous solvents these forces may be referred to as hydration forces.

Hamaker constant
In the case of *particle* interactions, a material constant that measures the relative strength of the attractive van der Waals forces between two surfaces. Particles interacting through an intervening fluid medium will experience a reduced attractive potential due to the presence of the third component.

hard sphere interaction
A largely theoretical construct in which the *interaction potential* between approaching *particles* is assumed to equal zero, except upon contact where it goes abruptly to infinity (i.e., no interpenetration occurs).

noninteracting
If no barrier to *particle* approach, contact and adherence exists, the *particles* are said to be noninteracting. If the *primary minimum* is sufficiently deep, every *collision* will result in *particles* sticking together. The rate of *aggregation* will then be kinetically controlled (*diffusion-limited rate*).

2.4.4 Related Terms

critical coagulation concentration (CCC)
The molar concentration of electrolyte, C_0, necessary to induce rapid (*diffusion-limited*) *aggregation*. Experimentally determined by extrapolation of ln W versus ln C_0 to ln W=0, where W is the *stability ratio*.

coagulant
An electrolyte additive that induces *coagulation* in a *suspension*.

Schulze-Hardy rule
An empirical rule summarizing the general tendency of the *critical coagulation concentration* to vary inversely with the sixth power of the *counter ion* charge number of added electrolyte.

lyotropic series
An ordered series of ions indicating, in decreasing order, their effectiveness in

influencing the behavior of *colloidal dispersions*. Typically associated with an ion's relative propensity to *coagulate* a *dispersion*.

stability ratio
Ratio of the *diffusion-limited* to *reaction-limited rate* constants for *aggregation*. A large ratio indicates a high degree of *colloidal stability*, whereas a ratio of unity indicates that *diffusion-limited* conditions prevail and the system is *colloidally unstable*. The rate constants are determined experimentally from the initial rates of *aggregation*. Usually denoted by the symbol, *W*.

defoaming agent [antifoaming agent]
A *surfactant* that, when present in small amounts, prevents the formation of a foam or aides in the coalescence of bubbles.

dispersing agent [stabilizing agent, dispersant]
A substance that, when present in small amounts, facilitates the *dispersion* of *aggregates* and improves the *kinetic stability* of *particles*. For example, *polyelectrolytes* are often used as dispersing agents in *ceramic* processing.

surface active agent [surfactant]
A substance that lowers the interfacial tension between the solution in which it is dissolved, and other phases which are present (e.g., solid *particles* in a *suspension*), and, accordingly, is positively adsorbed at the *interface*.

polyelectrolyte
A macromolecular substance that, on dissolving in water or other ionizing solvent, dissociates to give polyions (polycations or polyanions) - multiple charged ions - together with an equivalent amount of *counter ions*. A *polyelectrolyte* can be a polyacid, a polybase, a polysalt or a polyampholyte. Frequently used as *dispersing agents* in *ceramic slurries*.

sedimentation
The settling of suspended *particles* or *droplets* due to the influence of gravity or an applied centrifugal field.

sedimentation volume
The volume of *particulate* sediment formed in a *suspension*. If the sediment is formed in a centrifugal field, the strength of this field should be explicitly indicated, otherwise normal gravity is understood.

Brownian motion [thermal motion]
Random fluctuations in the density of molecules in a liquid, due to thermal

energy, cause other molecules and small dispersed *particles* to move along random pathways. This random motion is termed Brownian motion, and is most noticeable for *colloidal particles*.

coacervation
When a *colloidal suspension* loses stability, a separation into two liquid phases may occur. This process is termed coacervation. The phase that is more concentrated in the colloid is the coacervate, and the other phase is the equilibrium solution.

2.4.5 Recommendations

deflocculant, dispersing aid
It is recommended that these terms not be used in the ceramic literature. (see *dispersing agent*)

2.5 Interfacial and Electrokinetic Properties

2.5.1 The Interface

interface
A boundary between two immiscible phases, at least one of which is condensed. Experimentally, the portion of the sample through which the first derivative of any concentration versus location plot has a measurable departure from zero. In a *suspension*, the region of contact between the *particle* surface and the suspending medium.

interfacial region [interphase]
The region that exists between two phases where the properties vary from those in the bulk.

surface region
The tridimensional region, extending from the free surface of a condensed phase towards the interior, where the properties differ from the bulk.

electrical double layer (EDL)
The term describes the non-random array of ions at an *interface* in which two oppositely charged layers coexist. For particles dispersed in a fluid, the EDL consists of the surface charge and the solution charge. The solution charge may be further subdivided into *Stern* and *diffuse* layers, which is often referred to as the triple layer model.

double layer thickness
Length characterizing the decrease of potential with distance from a charged *interface*. Typically defined as $1/\kappa$, where κ is the *Debye-Hückel parameter*. For low potentials it represents the distance over which the potential falls to $1/e$ or about one third, of the value of the surface potential.

diffuse layer
The region surrounding a suspended *particle* in which non-specifically adsorbed ions are accumulated and distributed by the opposing action of the electric field and *thermal motion*.

Stern layer [compact layer]
Counter and *co-ions* in immediate contact with a surface are said to reside in the Stern layer, and form with the fixed surface charge a molecular capacitor. Often equated with the immobile portion of the *electrical double-layer* that exists inside the *shear plane*.

inner Helmholtz plane (IHP)
At a charged *interface*, an imaginary plane representing the distance of closest approach of desolvated ions to the surface, and containing the ions or molecules that are specifically adsorbed.

outer Helmholtz plane (OHP)
At a charged interface, an imaginary plane representing the distance of closest approach of solvated (hyrdrated) ions to the surface. Often equated with the position of the *shear plane*.

shear plane [plane of shear, surface of shear]
In calculating the *electrokinetic potential* from electrokinetic phenomena it is often assumed that a sharp plane separates the liquid adhering to the solid surface from the mobile liquid. This imaginary plane is considered to lie close to the solid surface.

2.5.2 Adsorption Processes

adsorption
The process by which a substance is accumulated at an *interface* or in an *interfacial region*. Should not be confused with absorption, which denotes accumulation inside a material or phase.

adsorbate
A substance that is adsorbed at the *interface* or into the *interfacial region* of a substrate material or *adsorbent*.

adsorbent
The substrate material onto which a substance is adsorbed.

adsorption isotherm
The relationship between the equilibrium quantity of a substance adsorbed and the composition of the bulk phase, at constant temperature.

specific adsorption
Ions are specifically adsorbed when they are present in the *Stern layer* in amounts that exceed those expected from simple electrostatic considerations. Empirically, ions that are specifically adsorbed have a noticeable effect on the *isoelectric point.*

non-specific adsorption
Ions are non-specifically adsorbed when they are kept in the *interphase* only by long-range coulombic interactions. They are believed to retain their solvation shell and in the position of closest approach to the *interface* they are separated from it by one or more solvent molecular layers. Empirically, ions that are non-specific (*indifferent*) have no measurable effect on the value of the *isoelectric point.*

chemical adsorption [chemisorption]
Molecules are chemically adsorbed when they exist within the *Stern layer* and form bonds with the surface groups, which have a significant valence contribution. Empirically, ions that are chemically adsorbed have a noticeable effect on the *isoelectric point* of a *suspension* and exhibit a significant enthalpy (heat of *adsorption*).

physical adsorption [physisorption]
Adsorption in which the forces involved are intermolecular (i.e., van der Waals, hydrogen bonding) of the same kind as those responsible for the non-ideality of real gases and the condensation of vapors, and which do not involve a significant change in the electronic orbital patterns of the species involved.

monolayer adsorption
Adsorption in which only a single layer of molecules becomes adsorbed at an *interface*. In monolayer adsorption, all adsorbed molecules are in the position of closest approach to the substrate surface.

multilayer adsorption
Adsorption in which more than a single layer of molecules is adsorbed at the *interface*. Molecules adsorbed in excess of *monolayer adsorption* are not in the position of closest approach to the substrate surface.

coadsorption
The simultaneous *adsorption* of two or more species.

desorption
The process by which the amount of an adsorbed substance is reduced.

2.5.3 Electrical Properties

isoelectric point (IEP)
For many ceramic systems, the pH at which dispersed *particles* show no *electrophoretic mobility* and the *zeta potential* has a value of zero. More generally, the p*I* value at which zeta is zero, where *I* is the *potential determining ion.*

point of zero charge (PZC)
A *particle* carrying no fixed charge. The precise identification of pzc depends on the definition adopted for surface charge. Typically for *ceramic* systems, the pH at which hydroxyl and proton *adsorption* is just balanced to cancel net charge; here, the hydroxyl and proton are defined as the charge determining species.

surface charge density
The quantity of electrical charge accumulated at a particle-solution *interface*, expressed per unit area; usually represented by the symbol σ_0.

streaming potential
When a liquid under a pressure gradient is forced through a capillary or porous plug, excess charges (ions) near the wall are swept along by the liquid creating an accumulation of charge downstream. An electric field is also created, which opposes this accumulation. After a steady state has been established, the measured potential difference across the capillary or plug is called the streaming potential and is related to the pressure gradient and to the *shear plane potential.*

zeta potential [electrokinetic potential, shear plane potential]
The potential drop, ζ, across the mobile part of the *electrical double layer*, that is responsible for the *electrokinetic* phenomena. ζ is positive if the potential increases from the bulk of the liquid phase towards the *shear plane.* Certain assumptions or estimations regarding the double layer properties must be made in order to calculate ζ from experimental data. It is therefore essential to indicate in all cases which equations have been used in the calculation of ζ. It can be shown, however, that for the same assumptions about the double

layer properties, all *electrokinetic* phenomena must give the same value for the *electrokinetic* potential.

potential determining ions
Those species of ions that by virtue of their equilibrium distribution between two phases determine the difference in Galvani potential between these phases. They are often, but not always, identical with the ions that stabilize a *colloidal suspension* formed from these phases.

co-ions
In systems containing large ionic species (e.g., *colloids*), co-ions are those that, compared to the large ions, have low molecular mass and the same polarity. For instance, in a *suspension* of negatively charged *particles* containing sodium chloride, the chloride ions are co-ions and the sodium ions are *counterions*.

counterions
In systems containing large ionic species (e.g., *colloids*), counterions are those that, compared to the large ions, have low molecular mass and the opposite polarity. For instance, in a *suspension* of negatively charged *particles* containing sodium chloride, the sodium ions are counterions and the chloride ions are *co-ions*.

charge reversal
The process wherein a charged *particle* is caused to assume a new charge of the opposite polarity. Such a change can be brought about by oxidation, reduction, dissociation, *adsorption* or ion exchange.

2.5.4 Electrokinetic Effects

electrokinetics
Referring to the relative motions of charged species in an electric field. The field may be applied, or it may be created by the motion of a liquid or adjacent solid phase.

electro-osmosis
When a liquid moves in response to an applied electric field, while an adjacent solid phase remains stationary (e.g., in a capillary or porous plug), this is called electro-osmotic flow. Fluid motion is due to the reaction of charged species within the fluid, usually dissolved ions, to the applied field.

electrophoresis
The motion of charged *particles* in an applied electric field.

electrophoretic mobility (static, dynamic)
The *electrophoretic* velocity per unit field strength, symbol $\mu_e=v/E$; μ_e is positive if the *particle* moves toward lower potential and negative in the opposite direction. When measured in a d.c. electric field, μ_e is referred to as the static mobility. When measured in a high-frequency field it is referred to as the dynamic mobility, and given the symbol μ_d or $\mu(\omega)$. Dynamic mobility may be a complex quantity at high frequencies.

electroacoustics
Referring to the electric-acoustic coupling in a fluid containing charged colloids or ions; an effect that is responsible for the *electrokinetic sonic amplitude*, *colloid vibration potential* and *ion vibration potential.*

acoustophoresis
The induced motion of *particles* subjected to an acoustic field. Charged *particles* will generate an electric field as a result of this motion (see *ultrasonic vibration potential*).

ultrasonic vibration potential (UVP)
When a sound wave propagates through a fluid containing charged *particles* (ions or *colloids*), coherent *acoustophoretic* motion of the *particles* creates alternating dipoles that generate a macroscopic potential difference termed the ultrasonic vibration potential.

ion vibration potential (IVP)
The *ultrasonic vibration potential* of an ionic solution; also known as the Debye effect.

colloid vibration current (CVI)
The alternating electrical current generated by the vibration potential of a colloidal suspension. The CVI is related to dynamic mobility of the *particles*; related to *colloid vibration potential.*

colloid vibration potential (CVP)
The *ultrasonic vibration potential* of a *colloidal suspension.* The resulting potential difference is related to the *dynamic mobility* of the *particles*; reciprocal effect to *electrokinetic sonic amplitude.*

electrokinetic sonic amplitude (ESA)
When a high-frequency alternating electric field is applied to a *dispersion* of charged *colloids*, the oscillatory *electrophoretic* motion of the *particles* relative to the surrounding medium results in a measurable acoustic field whose amplitude is related to the *dynamic mobility*; reciprocal effect of *colloid vibration potential*. The phase difference between the applied field and the resulting acoustic response can also be used to estimate the particle size distribution.

2.5.5 Related Terms

amphoteric
Refers to a type of surface in which the same surface group (reactive site) is able to function as both an acid and a base. That is, the site may dissociate to release a proton or accept a proton.

zwitterionic
Refers to a type of surface in which two distinct surface groups (reactive sites) are present. One is capable of dissociating to release a proton (acid group), and the other is capable of accepting a proton (base group).

hydrophilic
May be used to describe the character of interaction of a particular atomic group (or substance) with an aqueous medium. In this usage the term has the relative qualitative meaning of "water loving." The more general term, lyophilic ("solvent loving"), is used to distinguish a class of colloidal systems.

hydrophobic
The tendency of hydrocarbons (or of lipophilic hydrocarbon-like groups in solutes) to form intermolecular *aggregates* in an aqueous medium, and analogous intramolecular interactions. In this usage the term has the relative qualitative meaning of "water fearing." The more general term, lyophobic ("solvent fearing"), is used to distinguish a class of colloidal systems.

indifferent electrolyte [supporting electrolyte]
An ionic solution, whose constituents are not electroactive (i.e., they have no significant effect on the surface potential of the material under study; no oxidative or reductive capacity) in the range of applied potentials being studied, and whose ionic *strength* (and, therefore, contribution to the conductivity) is usually much larger than the concentration of an electroactive substance to be dissolved in it. The ions constituting an indifferent electrolyte are said to exhibit no specificity for the *particle* surface.

ionic strength
A measure of electrolyte concentration given by $I=\frac{1}{2}\sum c_i z_i^2$, where c_i are the concentrations, in moles per liter, of the individual ions, i, and z_i are their ion charge numbers.

Debye-Hückel parameter
A parameter in the Debye-Hückel theory of electrolyte solutions, denoted as κ. For aqueous solutions at 25 °C, $\kappa=3.288\sqrt{I}$ in reciprocal nanometers, where I is the *ionic strength*. See *double layer thickness*.

double layer compression [screening]
Increasing *ionic strength* causes the electrical potential near a charged surface to fall off more rapidly with distance. This is referred to as double layer compression or screening, because the *double layer thickness* shrinks as the *Debye-Hückel parameter* increases with increasing *ionic strength*.

electroviscous effects
For *dispersions* of charged *particles*, these are those components of the viscosity connected with the charge on the *particles*.

suspension effect
The Donnan e.m.f. between a *suspension* and its equilibrium liquid. The effect is most commonly encountered with pH measurements in *colloidal suspensions*.

potentiometric analysis
Analysis based on the measurement of electrical potential using, for example, a pH or ion-selective electrode. Potentiometry is often combined with *titrimetric analysis* in the determination of *particle* surface charge.

titrant
The solution containing the active agent with which a *titration* is made.

titration
The process of determining the amount of a substance A by adding increments of substance B with provision for some means of recognizing the point at which all of A has reacted. This allows the amount of A to be found from the known amount of B added up to this point.

titrimetric analysis
Analysis of test sample properties based on *titration*.

2.6 Bibliography

2.6.1 Primary Sources

Compendium of Chemical Terminology - IUPAC Recommendations, Compiled by V. Gold, K.L. Loening, A.D. McNaught, and P. Sehmi, Blackwell Scientific Publications, Oxford, UK, 1987.

L.L. Schramm, *The Language of Colloid and Interface Science - A Dictionary of Terms*, American Chemical Society, Washington, DC, 1993.

R.J. Hunter, *Foundations of Colloid Science*, Volume 1, Oxford University Press, Oxford, UK, 1989.

P.C. Hiemenz and R. Rajagopalan, *Principles of Colloid and Surface Chemistry*, 3rd Edition, Marcel Dekker, NY, 1997.

G.Y. Onoda and L.L. Hench, "Physical Characterization Terminology," Chapter 5, pp. 35-37 in *Ceramic Processing Before Firing*, Edited by G.Y. Onoda and L.L. Hench, John Wiley & Sons, NY, 1978.

2.6.2 Other Sources

Adsorption of Inorganics at Solid-Liquid Interfaces, Edited by M.A. Anderson and A.J. Rubin, Ann Arbor Science Publishers, Ann Arbor, MI, 1981.

Chemical Processing of Ceramics, Edited by B.I. Lee and E.J.A. Pope, Marcel Dekker, NY, 1994.

Sample Preparation for the Determination of Particle Size Distribution of Ceramic Powders, ISO/DIS 14703, 1998.

Particle Size Analysis: Dispersing Agents for Powders in Liquids, ISO Working Document 14887, 1997.

Surface and Colloid Chemistry in Advanced Ceramics Processing, Edited by R.J. Pugh and L. Bergström, Marcel Dekker, NY, 1994.

Ultrasonic and Dielectric Characterization Techniques for Suspended Particulates, Edited by V.A. Hackley and J. Texter, American Ceramic Society, Westerville, OH, 1998.

Bibliography

C.J. Brinker and G.W. Scherer, *Sol-Gel Science*, Academic Press, NY, 1990.

D.F. Evans and H. Wennerström, *The Colloidal Domain*, VCH Publishers, NY, 1994.

E.K. Fischer, *Colloidal Dispersions*, John Wiley & Sons, NY, 1950.

R.J. Hunter, *Zeta Potential in Colloid Science - Principles and Applications*, Academic Press, NY, 1981.

D. Myers, *Surfaces, Interfaces, and Colloids - Principles and Applications*, Chapter 10, "Colloids and Colloidal Stability," VCH Publishers, NY, 1991.

D.H. Napper, *Polymeric Stabilization of Colloidal Dispersions*, Academic Press, NY, 1983.

R.H. Ottewill, "Stability and Instability in Dispersed Systems," *Journal of Colloid and Interface Science*, 58, 357-373 (1977).

Th.F. Tadros, "Control of the Properties of Suspensions," *Colloids and Surfaces*, 18, 137-173 (1986).

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3. NOMENCLATURE FOR RHEOLOGICAL MEASUREMENTS

3.1 Fundamental Rheological Properties

elastic A conservative property in which part of the mechanical energy used to produce *deformation* is stored in the material and recovered on release of *stress*.

electroviscous The collective effects by which the presence of an electrical double-layer influences the *flow* behavior of a liquid. The double-layer is usually associated with charged particles suspended in the liquid or polyelectrolytes dissolved in solution. There are three electroviscous effects:

> **primary** The increase of fluid viscosity due to distortion of the double layer during *shear*. Distortion exerts a drag, increasing energy dissipation.
>
> **secondary** The increase of fluid viscosity due to the interaction or overlap of adjacent double-layers. Responsible for the formation of gelatin.
>
> **tertiary** The variation in fluid viscosity that arises from geometrical changes within the fluid due to double-layer interactions. The viscosity of a polyelectrolyte solution depends on the conformation of the molecules, which in turn is affected by intramolecular electrostatic interactions between charged segments located along the polymer backbone or on side chains.

plastic The property of a solid body that is in the *elastic* state when the *stress* is below a critical value, termed the *yield* stress, and in the plastic state when this value is exceeded. During ideal plastic *flow*, energy dissipation and stress are independent of the rate of *deformation*.

viscoelastic A time-dependent property in which a material under *stress* produces both a *viscous* and an *elastic* response. A viscoelastic material will exhibit viscous *flow* under constant stress, but a portion of mechanical energy is conserved and recovered after stress is released. Often associated with polymer solutions, melts and structured suspensions, viscoelastic properties are usually measured as responses to an instantaneously applied or removed constant *stress* or *strain* or a *dynamic* stress or strain.

viscoelectric An effect by which the electric field near a charged interface influences the structure of the surrounding fluid and thereby modifies the viscosity of the fluid.

viscoplastic A hybrid property in which a material behaves like a solid below some critical *stress* value, the *yield stress*, but flows like a viscous liquid when this stress is exceeded. Often associated with highly aggregated suspensions and polymeric gels.

viscous The tendency of a liquid to resist *flow* as a result of internal friction. During viscous flow, mechanical energy is dissipated as heat and the stress that develops depends on the rate of *deformation*.

3.2 Functional Forms of Viscosity

Viscosity nomenclature related to oscillatory measurements is defined here in general terms, but are described more explicitly in section 8.

apparent viscosity, η_{app} The value of viscosity evaluated at some nominal average value of the *shear rate*. The apparent viscosity applies, for instance, in the *capillary method*, where a range of shear rates are employed.

coefficient of fluidity [fluidity], ϕ Reciprocal of the *coefficient of viscosity*.

$$\phi = 1 / \eta$$

coefficient of viscosity [viscosity], η The ratio of *shear stress* to *shear rate* under simple *steady shear*. The abbreviated form "viscosity" is used most often in practice, and is frequently employed without discriminating between Newtonian and non-Newtonian behavior. When the quotient is independent of shear rate (i.e., follows the *Newtonian* model), it is considered a material constant. When the quotient is dependent on shear rate (i.e., *non-Newtonian*), it should be referred to as the **non-Newtonian viscosity**.

$$\eta = \sigma / \dot{\gamma}$$

complex viscosity, η^* The frequency-dependent viscosity function determined during *forced harmonic oscillation of shear stress*; contains both real and imaginary parts.

differential viscosity, η_{diff} The derivative of *shear stress* with respect to *shear rate*.

$$\eta_{diff} = \partial\sigma / \partial\dot{\gamma}$$

dynamic viscosity, η' The ratio of the *loss modulus* to the angular frequency, determined during *forced harmonic oscillation* (dynamic) measurements. The real part of the *complex viscosity*.

$$\eta' = G'' / \omega$$

infinite shear viscosity, η_∞ The high *shear rate* limiting value of viscosity. Often associated with the second *Newtonian* region in *pseudoplastic* fluids.

inherent viscosity [logarithmic viscosity], η_{inh} A natural logarithmic function of the *relative viscosity* reduced by the solute concentration.

$$\eta_{inh} = \frac{\ln \eta_r}{c}$$

intrinsic viscosity [limiting viscosity number], $[\eta]$ The zero concentration limiting value of the *reduced specific viscosity*. A characteristic function for the single molecule in solution. $[\eta]$ is equivalent to the effective hydrodynamic specific volume for the solute.

$$[\eta] = \lim_{c \to 0} \eta_{red}$$

kinematic viscosity, ν The ratio of the viscosity of a fluid to its density.

$$\nu = \eta_s / \rho$$

out-of-phase viscosity, η'' The ratio of the *storage modulus* to the angular frequency, determined during *forced harmonic oscillation* (dynamic) measurements. The imaginary part of the *complex viscosity*.

$$\eta'' = G' / \omega$$

plastic viscosity, η_{pl} For a *Bingham* model, the excess of the *shear stress* over the *yield stress* divided by the *shear rate*, and equal to the *differential viscosity*. For *non-ideal Bingham* materials, the differential viscosity determined in the high-shear limiting, linear portion of the *flow curve*; associated with viscoplastic fluids.

$$\eta_{pl} = \lim_{\dot{\gamma} \to \infty} \partial\sigma / \partial\dot{\gamma}$$

reduced viscosity [viscosity number], η_{red} The ratio of any viscosity function to the concentration, c, of the solute or particulate phase. By normalizing viscosity in this way, concentration effects become more apparent. For instance, the reduced *specific viscosity* is:

$$\eta_{red} = \eta_{sp} / c$$

relative viscosity [viscosity ratio], η_r Ratio of the viscosity in a suspension or solution to the viscosity of the suspending medium or solvent.

$$\eta_r = \eta / \eta_S$$

specific viscosity, η_{sp} The *relative viscosity* minus unity.

$$\eta_{sp} = \eta_r - 1$$

zero shear viscosity, η_0 The low *shear rate* limiting value of viscosity. Associated with the first *Newtonian* region in many *pseudoplastic* fluids.

$$\eta_0 = \lim_{\dot{\gamma} \to 0} \eta$$

3.3 Glossary of Basic Terminology

apparent yield stress For non-ideal *viscoplastic* materials, where the *yield stress* is indefinite, an apparent yield stress can be defined, for example, by extrapolation from the linear, high-*shear-rate* portion of the *flow curve* to the stress axis. (see *Bingham* relation)

compliance The quotient of *strain* and *stress* (e.g., *shear compliance*). The reciprocal of *modulus*.

deformation Movement of parts or particles of a material body relative to one another such that the continuity of the body is not destroyed, resulting in a change of shape or volume or both.

dilatant A property often associated with suspensions of irregularly shaped particles, in which the liquid exhibits an increase in volume while being sheared. The term is also used in common practice to mean *shear-thickening*, the increasing resistance to shear with increasing *shear rate*. It is possible for either of these two effects to exist in the absence of the other.

dynamic equilibrium A state in which dynamic opposing forces just balance to obtain a quasi-equilibrium condition. Dynamic equilibrium is achieved during steady shear flow when break down and rebuilding of *structure* occur at similar rates, and the viscosity is constant at a given *shear rate.*

dynamic [oscillatory] shear flow Condition under which *stress* and *strain* vary harmonically with time during a *rheometric* experiment.

Einstein's Law of Viscosity Describes the relationship between the viscosity of a dilute dispersion and the volume fraction of the dispersed particles. The relationship is derived with two major assumptions, that the particles are solid spheres and that their concentration is very low.

$$\frac{\eta}{\eta_S} = 1 + 2.5\phi + ...$$

where η_S is the viscosity of the suspending medium and ϕ is the volume fraction. The factor 2.5 is known as the **Einstein coefficient**. To describe more concentrated dispersions, higher terms in the power series have been retained and analyzed with varying success.

equilibrium [steady state] flow Condition under which a constant *stress* or *shear rate* is maintained for a sufficient time to allow *dynamic equilibrium* to be achieved in a fluid containing time-dependent *structure.* An equilibrium *flow curve* can be used to characterize the time-independent *flow* properties of a material.

elastic modulus [modulus of elasticity] A *modulus* of a body that obeys *Hooke's law.*

flow Continuously increasing *deformation* of a material body under the action of finite forces. When the force is removed, if the *strain* does not eventually return to zero, then flow has occurred.

flow curve A graphical representation of the behavior of flowing materials in which *shear stress* is related to *shear rate.*

Hooke's law Provides that the quotient of *stress* and *strain* (i.e., the *modulus*) is a constant. A body obeying Hooke's law cannot be *viscoelastic* nor does *flow* occur.

laminar flow *Flow* without turbulence.

modulus The quotient of *stress* and *strain* where the type of stress and strain is defined by the type of *deformation* employed (e.g., *shear modulus* in shear deformation).

Navier-Stokes equations The equations of motion for a *Newtonian* fluid model describing the balance between external forces (like gravity), the pressure force and the viscous force.

Newtonian *Flow* model of fluids in which a linear relationship exists between *shear stress* and *shear rate*, where the *coefficient of viscosity* is the constant of proportionality.

no-slip Condition in which fluid adjacent to a surface moves with the velocity of that surface. The assumption of no-slip is key to most *rheometric* measurements. Slippage is a significant concern in concentrated suspensions.

non-equilibrium flow Condition under which *shear* is varied at a rate that does not permit *dynamic equilibrium* to be achieved. A *thixotropic loop* is the result of non-equilibrium flow conditions during shear cycling.

non-Newtonian Any *laminar flow* that is not characterized by a linear relationship between *shear stress* and *shear rate*.

normal stress, σ_n The component of stress that acts in a direction normal to the plane of *shear*.

Peclet number, *Pe* A dimensionless group used to compare the effect of applied shear with the effect of thermal (Brownian) motion; $Pe=r^2\dot{\gamma}/D$, where r is the particle radius and D is the translational diffusion coefficient. For $Pe << 1$, particle behavior is dominated by diffusional relaxation, whereas for $Pe >> 1$, hydrodynamic effects dominate.

Poiseuille flow *Laminar flow* in a pipe of circular cross section under a constant pressure gradient. (see also *Capillary Methods*)

Reynolds number, *Re* A dimensionless group that expresses the ratio of the inertial forces to the viscous forces; $Re=Dv\rho/\eta$, where D is a characteristic length (e.g., particle size or pipe diameter), v is a typical fluid speed, and η/ρ is the *kinematic viscosity* of the fluid. The transition from *laminar* to turbulent *flow* is characterized by high *Re* values.

rheology The science of the *deformation* and *flow* of matter.

rheometric Refers to the measurement of rheological properties.

shear The relative movement of parallel adjacent layers.

shear compliance, J The ratio of *shear strain* to its corresponding *shear stress*. The reciprocal of *shear modulus*.

shear modulus [modulus of rigidity], G The ratio of *shear stress* to its corresponding *shear strain*. The reciprocal of *shear compliance*.

shear rate (rate of shear strain), $\dot{\gamma}$ The rate of change of *shear strain* with time ($d\gamma / dt$). For liquids, the *shear rate*, rather than *strain*, is generally used in describing *flow*.

shear stress, σ The component of *stress* that causes successive parallel layers of a material body to move, in their own planes (i.e., the plane of *shear*), relative to each other.

shear strain, γ The relative in-plane displacement, Δx, of two parallel layers in a material body divided by their separation distance, y. Alternatively, the shear strain can be defined as *tan* θ, where θ is the angle of deformation as shown in Figure 1.

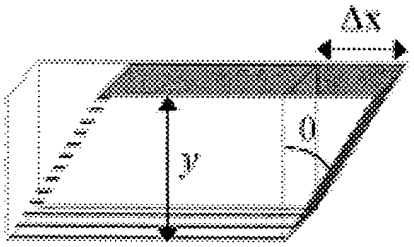

Fig. 1. Shear strain schematic.

shear-thickening An increase in viscosity with increasing *shear rate* during *steady shear flow*. The term *dilatant* is commonly used in practice to indicate shear-thickening, although this usage is strictly incorrect.

shear-thinning [pseudoplastic] A decrease in viscosity with increasing *shear rate* during *steady shear flow*.

simple shear In simple *shear* there is no change in the dimension normal to the plane of shear, and the relative displacement of successive parallel layers of a material body are proportional to their distance from a reference layer. The type of *flow* used in most *rheometric* measurements on fluids can be approximated by simple shear.

steady shear flow Condition under which a fluid is sheared continuously in one direction during the duration of a *rheometric* experiment.

stress Force per unit area.

structure In *rheology*, structure is a term that refers to the formation of stable physical bonds between particles (or chemical bonds between macromolecules) in a fluid. These bonds result in aggregate, floc, or network structure, which impacts the rheological behavior of the fluid and provides *elastic* and *plastic* properties. The term may be extended to include structural effects caused by *electroviscous* interactions, physical bonds between polymers (e.g., associative thickeners), shear-induced alignment of anisotropic particles, and close-packing (radial distribution) correlations in concentrated suspensions. The term "structure" is commonly invoked even when little is known about the cause of observed changes in rheological properties.

Weissenberg effect The tendency of some *viscoelastic* fluids to *flow* in a direction normal to the direction of *shear*. The effect is manifested by behavior such as the climbing of a fluid up a rotating rod.

Weissenberg number, *Wi* A measure of the degree of nonlinearity or the degree to which *normal stress* differences are exhibited in a *flow*. For *steady, simple shear*, the Weissenberg number is the product of the *shear rate* and a characteristic time of the fluid. In oscillatory shear it is the product of the shear rate amplitude and the characteristic time of the fluid. In converging flows it is proportional to the *Deborah number*.

yield response For non-ideal *viscoplastic* materials, the *yield stress* can be indefinite and yielding may occur continuously over a narrow range of *stress* values. In this case, the behavior may be more properly termed a yield response.

yield stress, σ_y A critical *shear stress* value below which an ideal *plastic* or *viscoplastic* material behaves like a solid (i.e., will not flow). Once the yield stress is exceeded, a plastic material yields (deforms plastically) while a viscoplastic material flows like a liquid.

3.4 Classification of Equilibrium Flow Curves

Steady-shear flow curves for suspensions and solutions measured under equilibrium conditions may exhibit a variety of behaviors over a limited range of *shear rates*. Additionally, some materials may exhibit more than one distinct behavior over different shear rate regions of the same flow curve. Several types of behavior can be classified according to their characteristic shape. The following classification system covers the six most frequently encountered flow types as illustrated in the accompanying graph.

1. **Newtonian** *Differential viscosity* and *coefficient of viscosity* are constant with *shear rate*.

2. **shear-thickening** *Differential viscosity* and *coefficient of viscosity* increase continuously with *shear rate*.

3. **shear-thinning [pseudoplastic]** *Differential viscosity* and *coefficient of viscosity* decrease continuously with *shear rate*. No *yield* value.

4. **shear thinning [pseudoplastic] with yield response** *Differential viscosity* and *coefficient of viscosity* decrease continuously with *shear rate* once the apparent *yield stress*, σ_{app}, has been exceeded.

5. **Bingham plastic (ideal)** Obeys the *Bingham relation* ideally. Above the Bingham *yield* stress (σ_B in Figure 2) the *differential viscosity* is constant and is called the *plastic viscosity*, while the *coefficient of viscosity* decreases continuously to some limiting value at infinite *shear rate*.

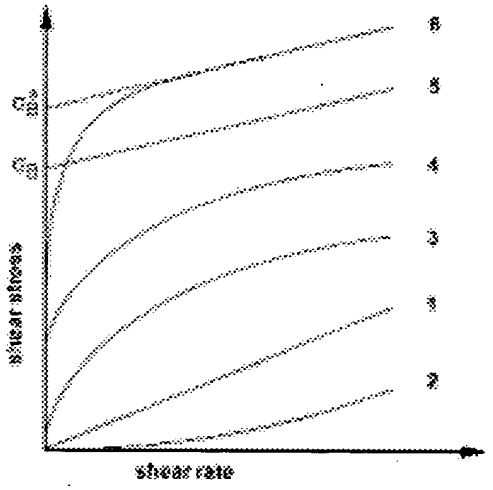

Fig. 2. Identification of flow curves based on their characteristic shape.

6. **Bingham plastic (non-ideal)** Above the apparent *yield* stress the *coefficient of viscosity* decreases continuously, while the *differential viscosity* approaches a constant value with increasing *shear rate*. Extrapolation of the *flow curve* from the linear, high shear rate region (plastic region) to the

stress axis gives the apparent *Bingham* yield stress (σ_B* in Figure 2). The *differential viscosity* in the linear region is termed the *plastic viscosity.*

3.5 Expressions for Describing Steady Shear Non-Newtonian Flow

The expressions shown in this section are used to characterize the *non-Newtonian* behavior of fluids under equilibrium, *steady shear flow* conditions. Many phenomenological and empirical models have been reported in the literature. Only those having a direct and significant implication for suspensions, gels and pastes have been included here. A brief description of each relationship is given with examples of the types of materials to which it is typically applied. In defining the number of parameters associated with a particular model, the term "parameter" in this case refers to adjustable (arbitrary) constants, and therefore excludes measured quantities. Some of these equations have alternative representations other than the one shown. More detailed descriptions and alternative expressions can be found in the sources listed in the bibliography.

Bingham

$$\sigma = \sigma_B + \eta_{pl}\dot{\gamma}$$

$$\dot{\gamma} = 0 \text{ for } \sigma < \sigma_B$$

The Bingham relation is a two parameter model used for describing *viscoplastic* fluids exhibiting a *yield response.* The ideal Bingham material is an elastic solid at low *shear stress* values and a *Newtonian* fluid above a critical value called the Bingham *yield stress*, σ_B. The *plastic viscosity* region exhibits a linear relationship between shear stress and *shear rate*, with a constant *differential viscosity* equal to the *plastic viscosity*, η_{pl}.

Carreau-Yasuda

$$\frac{\eta - \eta_\infty}{\eta_0 - \eta_\infty} = \left[1 + (\lambda\dot{\gamma})^a\right]^{(n-1)/a}$$

A model that describes *pseudoplastic* flow with asymptotic viscosities at zero (η_0) and infinite (η_∞) *shear rates*, and with no *yield stress*. The parameter λ is a constant with units of time, where $1/\lambda$ is the critical shear rate at which viscosity begins to decrease. The *power-law* slope is (n-1) and the parameter *a*

represents the width of the transition region between η_0 and the power-law region. If η_0 and η_∞ are not known independently from experiment, these quantities may be treated as additional adjustable parameters.

Casson

$$\sigma^{1/2} = \sigma_y^{1/2} + \eta_{pl}^{1/2}\,\dot{\gamma}^{1/2}$$

$$\dot{\gamma} = 0 \text{ for } \sigma < \sigma_y$$

A two parameter model for describing *flow* behavior in *viscoplastic* fluids exhibiting a *yield response*. The parameter σ_y is the *yield stress* and η_{pl} is the differential high shear (*plastic*) viscosity. This equation is of the same form as the *Bingham* relation, such that the exponent is 1/2 for a Casson plastic and 1 for a Bingham plastic.

Cross

$$\frac{\eta - \eta_\infty}{\eta_0 - \eta_\infty} = \frac{1}{\left(1 + \lambda\dot{\gamma}^m\right)}$$

A model, similar in form to the *Carreau-Yasuda* relation, that describes *pseudoplastic* flow with asymptotic viscosities at zero (η_0) and infinite (η_∞) *shear rates*, and no *yield stress*. The parameter λ is a constant with units of time, and *m* is a dimensionless constant with a typical range from 2/3 to 1. If η_0 and η_∞ are not known independently from experiment, these quantities may be treated as additional adjustable parameters.

Ellis

$$\eta = \frac{\eta_0}{1 + \left(\sigma/\sigma_2\right)^{\alpha-1}}$$

A two parameter model, written in terms of *shear stress*, used to represent a *pseudoplastic* material exhibiting a *power-law* relationship between *shear stress* and *shear rate*, with a low shear rate asymptotic viscosity. The parameter σ_2 can be roughly identified as the shear stress value at which η has fallen to half its final asymptotic value.

Herschel-Bulkley

$$\sigma = \sigma_y + k\dot{\gamma}^n$$

A three parameter model used to describe *viscoplastic* materials exhibiting a *yield response* with a *power-law* relationship between *shear stress* and *shear rate* above the *yield stress*, σ_y. A plot of log $(\sigma - \sigma_y)$ versus log $\dot{\gamma}$ gives a slope n that differs from unity. The Herschel-Bulkley relation reduces to the equation for a *Bingham* plastic when n=1.

Krieger-Dougherty

$$\eta_r = \left(1 - \Phi/\Phi_m\right)^{-[\eta]\Phi_m}$$

A model for describing the effect of particle self-crowding on suspension viscosity, where Φ is the particle volume fraction, Φ_m is a parameter representing the maximum packing fraction and $[\eta]$ is the *intrinsic viscosity*. For ideal spherical particles $[\eta]$=2.5 (i.e., the Einstein coefficient). Non-spherical or highly charged particles will exhibit values for $[\eta]$ exceeding 2.5. The value of $[\eta]$ is also affected by the particle size distribution. The parameter Φ_m is a function of particle shape, particle size distribution and *shear rate*. Both $[\eta]$ and Φ_m may be treated as adjustable model parameters.

The aggregate volume fraction (representing the effective volume occupied by particle aggregates, including entrapped fluid) can be determined using this equation if Φ_m is fixed at a reasonable value (e.g., 0.64 for random close packing or 0.74 for hexagonal close packing) and $[\eta]$ is set to 2.5. In this case, Φ is the adjustable parameter and is equivalent to the aggregate volume fraction.

Meter

$$\eta = \eta_\infty + \frac{\eta_0 - \eta_\infty}{1 + \left(\sigma/\sigma_2\right)^{\alpha-1}}$$

A model, expressed in terms of *shear stress*, used to represent a *pseudoplastic* material exhibiting a *power-law* relationship between *shear stress* and *shear rate*, with both high (η_∞) and low (η_0) shear rate asymptotic viscosity limits. The parameter σ_2 can be roughly identified as the shear stress value at which η has fallen to half its final asymptotic value. The Meter and *Carreau-Yasuda* models give equivalent representations in terms of shear stress and shear rate, respectively. If η_0 and η_∞ are not known independently from experiment, these quantities may be treated as additional adjustable parameters.

Powell-Eyring

$$\eta = \eta_\infty + (\eta_0 - \eta_\infty)\frac{\sinh^{-1}(\tau\dot{\gamma})}{\tau\dot{\gamma}}$$

Derived from the theory of rate processes, this relation is relevant primarily to molecular fluids, but can be used in some cases to describe the *viscous* behavior of polymer solutions and *viscoelastic* suspensions over a wide range of *shear rates*. Here, η_∞ is the *infinite shear viscosity*, η_0 is the *zero shear viscosity* and the fitting parameter τ represents a characteristic time of the measured system. If η_0 and η_∞ are not known independently from experiment, these quantities may be treated as additional adjustable parameters.

power-law [Ostwald-de Waele]

$$\sigma = K\dot{\gamma}^n$$

A two parameter model for describing *pseudoplastic* or *shear-thickening* behavior in materials that show a negligible *yield response* and a varying *differential viscosity*. A log-log plot of σ versus $\dot{\gamma}$ gives a slope n (the *power-law* exponent), where $n<1$ indicates pseudoplastic behavior and $n>1$ indicates shear-thickening behavior.

3.6 Time-Dependent Effects

Time-dependence includes those effects associated with transient flow conditions as well as those effects associated with irreversible changes that result from shear history.

creep The response of a material to the instantaneous application of a constant stress.

creep function In an applied stress test, where an instantaneous and constant stress is applied to a material while the *shear rate* (or *shear strain*) is measured over time, the shear rate (or strain) vs. time function is termed the *creep* function. The function $J(t)=\gamma(t)/F$ is referred to as the creep *compliance*.

Deborah number, *De* The ratio of a characteristic *relaxation time* of a material to the duration of the observation. In *equilibrium flow*, the effective duration of the experiment is infinity, and $De=0$. In oscillatory shear, it is the product of the frequency and the relaxation time of the fluid. In converging flows, the Deborah number is proportional to the *Weissenberg number.*

flow hysteresis A condition resulting from differences in the rate of energy dissipation due to *shear* history. In a typical rheometric test, *shear stress* or *shear rate* is ramped at a fixed speed up to a maximum value, then ramped back down at the same speed to the beginning. In hysteresis, one *flow curve* lies above the other, forming a continuous loop whose internal area depends on the shear and thermal history of the material, and on how rapidly the stress or shear rate was ramped. If the down-curve lies below the up-curve, then it is referred to as a *thixotropic* loop, whereas if the down-curve lies above the up-curve, then it is called a *negative thixotropic* loop.

negative thixotropy [anti-thixotropy] A reversible time-dependent increase in viscosity at a particular shear rate. Shearing causes a gradual growth in *structure* over time.

relaxation time, τ A time characterizing the response of a *viscoelastic* material to the instantaneous application of a constant *strain*.

retardation time, τ A time characterizing the response of a *viscoelastic* material to the instantaneous application of a constant *stress*.

rheomalaxis An irreversible decrease of viscosity during shearing. Attributed to permanent changes in the material *structure*.

rheopexy An effect by which a material recovers some of its pre-sheared viscosity at a faster rate when it is gently sheared compared to when it is allowed to stand. Not to be confused with *negative thixotropy*.

stress growth When an instantaneous and constant *strain* (or *shear rate*) is applied to a material while stress is measured over time, an increasing stress vs. time or *modulus* vs. time function is termed stress growth.

stress relaxation When an instantaneous and constant *strain* (or *shear rate*) is applied to a material while stress is measured over time, a decreasing stress vs. time or *modulus* vs. time function is termed stress relaxation.

thixotropy A reversible time-dependent decrease in viscosity at a particular *shear rate*. Shearing causes a gradual breakdown in *structure* over time.

3.7 Oscillatory Measurements

forced harmonic oscillation is a dynamic *rheometric* test in which both *stress* and *strain* vary harmonically with time, and both *viscous* and *elastic* parame-

ters are derived from the material response. Such tests are almost always carried out in the **linear viscoelastic regime**, which is characterized by a linear response of *dynamic viscosity* and *elasticity* with increasing *strain amplitude*.

3.7.1 Material Functions Derived from Oscillatory Tests

In a typical sinusoidal oscillation experiment, the applied stress and resulting *strain* wave forms can be described as follows:

$$\sigma = \sigma_0 \cos \omega t$$
$$\gamma = \gamma_0 \cos(\omega t - \delta)$$

where σ_0 is the **stress amplitude**
γ_0 is the **strain amplitude**
$\omega = 2\pi f$ is the angular frequency
t is time
δ is the **phase lag (loss angle)**

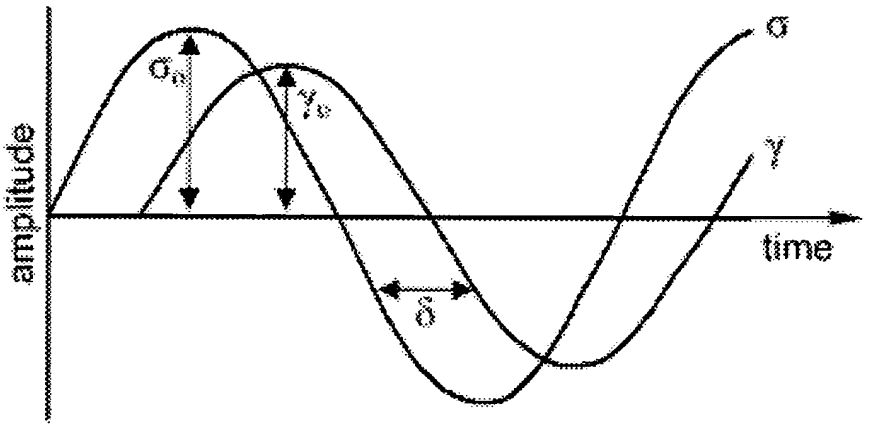

Fig. 3. Sinusoidal wave forms for stress and strain functions.

The phase lag and amplitude ratio (σ_0/γ_0) will generally vary with frequency, but are considered material properties under linear *viscoelastic* conditions. For an ideal solid, $\delta=0°$, and the response is purely *elastic*, whereas for a *Newtonian* fluid yielding a purely viscous response, $\delta=90°$.

The material functions can be described in terms of complex variables having both real and imaginary parts. Thus, using the relationship:

$$\cos x + j \sin x = e^{jx}$$

where $j = \sqrt{-1}$

Then the stress and strain can be expressed as follows:

$$\sigma = \Re\left(\sigma_0 e^{j\omega t}\right)$$
$$\gamma = \Re\left(\gamma_0 e^{j(\omega t - \delta)}\right) = \Re\left(\gamma_0 e^{-j\delta} e^{j\omega t}\right)$$

where $(\gamma_0 e^{-j\delta})$ is termed the complex strain amplitude. The **shear storage modulus** [or storage modulus, for short], which represents the in-phase (elastic) component of oscillatory *flow*, is defined as:

$$G' = \text{storage } \textit{modulus} = \frac{\sigma_0}{\gamma_0} \cos \delta$$

The out-of-phase (viscous) component is termed the **shear loss modulus** [or loss modulus, for short]:

$$G'' = \text{loss } \textit{modulus} = \frac{\sigma_0}{\gamma_0} \sin \delta$$

The **complex shear modulus**, G^*, is then defined as follows:

$$G^* = \frac{\text{complex stress amplitude}}{\text{complex strain amplitude}} = \frac{\sigma_0}{\gamma_0} \cos \delta + \frac{\sigma_0}{\gamma_0} j \sin \delta$$

so that:

$$G^* = G' + jG''$$
$$\text{Tan } \delta = G''/G'$$

The function G''/G' measures the relative importance of viscous to elastic contributions for a material at a given frequency.

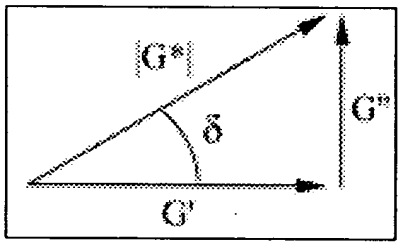

Fig. 4. Vectorial representation of moduli.

Additionally, a *complex viscosity*, η^*, can be defined using the complex strain rate, $\dot{\gamma} = j\omega\gamma$, such that:

$$\eta^* = \frac{\text{complex stress amplitude}}{\text{complex strain rate amplitude}} = \frac{\sigma_0}{j\gamma_0\omega} e^{j\delta} = G^*/j\omega$$

or alternatively

$$\eta^* = \eta' - j\eta''$$
$$\eta' = G''/\omega$$
$$\eta'' = G'/\omega$$

where η' is termed the *dynamic viscosity*, and is equivalent to the ratio of the stress in phase with the rate of strain ($\sigma_0 \sin \delta$) to the amplitude of the rate of strain ($\omega\gamma_0$). The term η'' is referred to as the *out-of-phase viscosity*, and is equivalent to the ratio of the stress 90° out of phase with the rate of strain ($\sigma_0 \cos \delta$) to the amplitude of the rate of strain ($\omega\gamma_0$) in the forced oscillation.

Finally, an **absolute shear modulus** is defined as the ratio of the amplitude of the stress to the amplitude of the strain in forced oscillation (*simple shear*), or:

$$|G^*| = \frac{\sigma_0}{\gamma_0} = (G'^2 + G''^2)^{1/2}$$

Alternatively, forced oscillation experiments can be equivalently described in terms of *compliance*, as opposed to the derivation above based on the modulus. Similar arguments lead to the following analogous terms:

complex shear compliance, J^* The ratio of the complex strain (γ^*) to complex stress (σ^*) in forced oscillation (simple shear).

shear storage compliance, J' The ratio of the amplitude of the strain in phase with the stress ($\gamma_0 \cos \delta$) to the amplitude of the stress (σ_0) in forced oscillation (simple shear).

shear loss compliance, J'' The ratio of the amplitude of the strain 90° out of phase with the stress ($\gamma_0 \sin \delta$) to the amplitude of the stress (σ_0) in forced oscillation (simple shear).

absolute shear compliance, $|J^*|$ The ratio of the amplitude of the strain (γ_0) to the amplitude of the stress (σ_0) in forced oscillation (simple shear).

3.8 Measurement Apparatus

There are two common methods used for *rheometric* measurements on fluid systems: capillary (or tube) and rotational. In this section, a brief summary is given for each general method along with descriptions of common measurement devices and geometries. Measurement devices can be grouped into one of two general classifications. A **viscometer** is a device used principally for the measurement of viscosity, while a **rheometer** is a device used for the measurement of rheological properties over a varied and extended range of conditions. More detailed descriptions of these instruments and methods can be found in the primary sources listed in the bibliography. Only a brief coverage is provided here.

3.8.1 Capillary Methods

In capillary methods the test fluid is made to flow through a narrow tube as a result of hydrostatic or applied pressure. Capillary measurements are considered the most precise way of determining the viscosity of *Newtonian* and some *non-Newtonian* viscous fluids, and are generally simpler in design and less expensive relative to *rotational* instruments. **Poiseuille's Law**, which relates the rate of flow through a capillary to the viscosity of the liquid, is the basis for the capillary method.

Glass Capillary Viscometer

Widely used for measuring the viscosity of *Newtonian* fluids, including dilute solutions and suspensions, the glass capillary viscometer is the simplest and least expensive viscometric system available commercially. Typically, in this technique, the time required for a given volume of fluid to flow through a defined length, L, of glass capillary under its own hydrostatic head is measured. The flow time, t, is related to the viscosity using a simple relationship derived from Poiseuille's Law, of the form:

$$\frac{\eta}{\rho} = At + \frac{B}{t}$$

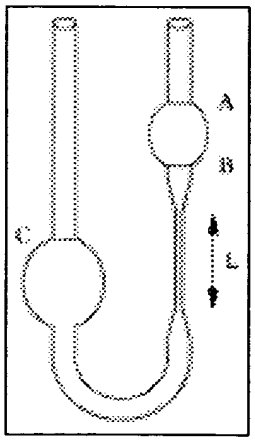

Fig. 5. Ostwald type capillary viscometer. A and B are timing marks, C is a filling mark.

where A and B are instrument constants. The second term on the right hand side is related to the kinetic energy correction, and can be ignored for long flow times. In this case, a simple linear equation results. The viscometer can be easily calibrated using a standard fluid with known viscosity at the measurement temperature. Capillaries with different diameters can be used for different viscosity ranges, while maintaining reasonable flow times.

Extrusion Capillary Viscometer
These instruments are widely used for measuring viscous fluids, such as asphalt cements, polymer melts, and stable concentrated suspensions. Extrusion viscometers have the advantage of high precision and simple design, and are less subject to temperature effects that can occur during shearing of highly viscous fluids in *rotational* devices.

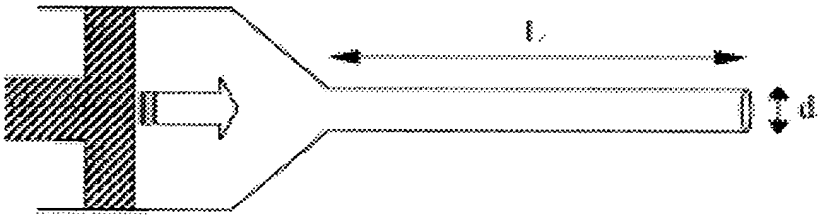

Fig. 6. Diagram of a simple extrusion viscometer.

Extrusion viscometers use a cylindrical piston to force the test fluid from a reservoir through the capillary tube at a constant velocity. By measuring the pressure drop across the capillary as a function of flow rate for multiple capillaries of the same diameter, d, but differing length, L, it is possible to determine the viscosity as a function of *shear rate*.

3.8.2 Rotational Methods

In rotational methods the test fluid is continuously sheared between two surfaces, one or both of which are rotating. These devices have the advantage of being able to *shear* the sample for an unlimited period of time, permitting transient behavior to be monitored or an equilibrium state to be achieved, under controlled *rheometric* conditions. Rotational methods can also incorporate *oscillatory* and *normal stress* tests for characterizing the *viscoelastic* properties of samples. In general, rotational methods are better suited for the measurement of concentrated suspensions, gels and pastes, but are generally less precise as compared to *capillary* methods.

Rotational measurements fall into one of two categories: **stress-controlled** or **rate-controlled**. In stress-controlled measurements, a constant torque is applied to the measuring tool in order to generate rotation, and the resulting rotation speed is then determined. If a well-defined tool geometry is used, the rotation speed can be converted into a corresponding *shear rate*. In rate-controlled measurements, a constant rotation speed is maintained and the resulting torque generated by the sample is determined using a suitable stress-sensing device, such as a torsion spring or strain gauge. Some commercial instruments have the capability of operating in either stress-controlled or rate-controlled modes.

Simple Rotational Viscometer ("Brookfield type")

The least expensive commercial variant of the controlled-rate rotational *viscometer* is commonly referred to as a "Brookfield type" viscometer§. This device measures fluid viscosity at fixed rotation speeds by driving a measurement tool ("spindle"), immersed in the test fluid, through a calibrated torsion spring. Viscous drag of the fluid against the spindle causes the spring to deflect, and this deflection is correlated with torque. The calculated *shear rate* depends on the rotation speed, the tool geometry and he size and shape of the sample container. Conversion factors are needed to calculate viscosity from the measured torque, and are typically pre-calibrated for specific tool and container geometries. For *Newtonian* fluids the torque is proportional to the product of viscosity and rotational speed, but this proportionality is lost in the case of a *non-Newtonian* fluid. Because these instruments are robust and fairly simple to use, they have found wide application in industry, but they offer limited capabilities and precision for research-oriented applications.

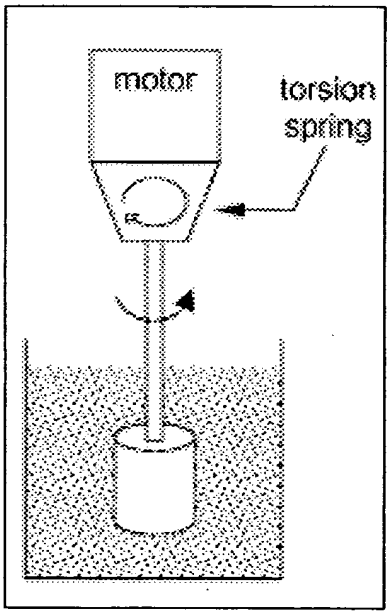

Fig. 7. Schematic diagram of a Brookfield-type viscometer.

Rotational Rheometer

High-precision, continuously-variable-*shear* instruments in which the test fluid is sheared between rotating cylinders, cones or plates, under controlled-stress or controlled-rate conditions, are termed rotational rheometers. Instruments producing *oscillatory* strains are available, and a few commercial

systems permit measurement of the *normal stress*. The basic rotational system consists of four parts: (i) a measurement tool with a well-defined geometry, (ii) a device to apply a constant torque or rotation speed to the tool over a wide range of *shear stress* or *shear rate* values, (iii) a device to determine the stress or shear rate response, and (iv) some means of temperature control for the test fluid and tool. Depending on the design specifications, rheometers may also include built-in corrections or compensations for inertia, drift, and temperature fluctuations during measurement.

Most rheometers are based on the relative rotation about a common axis of one of three tool geometries: concentric cylinder, cone and plate or parallel plates (See Figure 8).

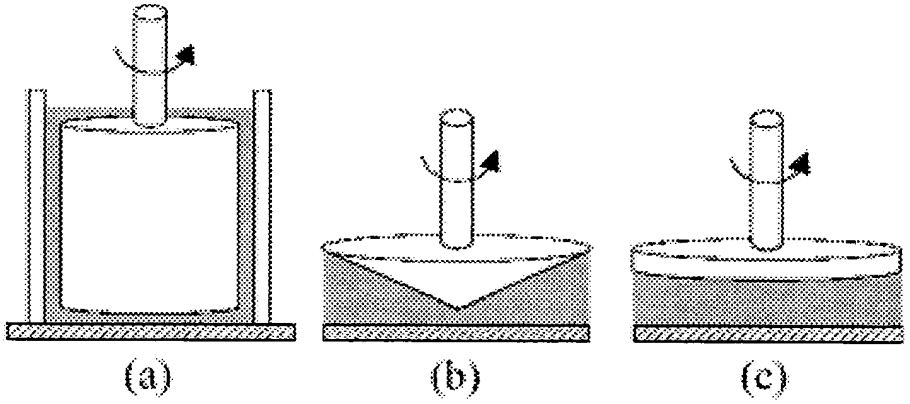

Fig. 8. Schematic diagram of basic tool geometries for the rotational rheometer: (a) concentric cylinder, (b) cone and plate, (c) parallel plate.

In the **concentric cylinder** (also called **Couette** or **Coaxial**) geometry either the inner, outer or both cylinders may rotate, depending on instrument design. The test fluid is maintained in the annulus between the cylinder surfaces. This tool geometry comes in several configurations, of which the three most commonly encountered are illustrated in Figure 9. The **double-gap** configuration is useful for low viscosity fluids, as it increases the total area, and therefore the viscous drag, on the rotating inner cylinder, and generally increases the accuracy of the measurement. The **cone** and **hollow cavity** configurations are specifically designed to reduce or account for end effects. In addition, to prevent slippage, the inner cylinder surface is sometimes serrated or otherwise

roughened. The concentric cylinder geometry is typically used for the analysis of fluid suspensions.

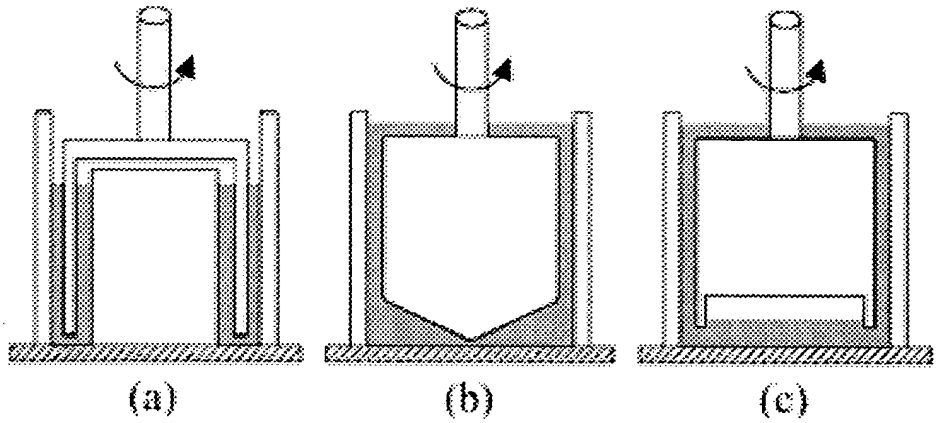

Fig. 9. Schematic diagram showing three alternative cylindrical tool designs in cut-away view: (a) double gap, (b) cone and plate at the bottom, (c) hollow cavity at the bottom to trap air.

The **cone and plate geometry** consists of an inverted cone in near contact with a lower plate. The cone is usually designed with an angle of less than 4°. Either the upper or lower surface may rotate depending on instrument design. The **parallel plate geometry** can be considered a simplified version of the cone and plate, having an angle of 0°. The test fluid is constrained in the arrow gap between the two surfaces. Cone and plate and parallel plate measurement tools are most often used for highly viscous pastes, gels, and concentrated suspensions.

3.9 Concrete and Other Coarse-Grained Materials

Ceramic materials are typically fabricated from particles in the subsieve or fine size range (i.e., less than roughly 37 μm), though coarse agglomerates may play a role during some phase of processing. On the other hand, concrete is classified as a ceramic material, but containing a considerably broader range of particle sizes, from less than one micrometer up to about 20 mm (i.e., well into the sieve range). This wide range results from the heterogeneous concrete composition, which includes cement (5 μm to 60 μm), mineral fillers (< 1 μm to 100 μm), fine aggregates (0.1 mm to 5 mm) and coarse aggregates (4 mm to 30 mm or higher in some special concretes) or stones.

As a result of the broad range of particle sizes and the presence of sieve-size particles, methods to measure the *flow* properties of concrete differ significantly from those methods specified for applications involving suspensions of fine particles. Test methods applied to concrete tend to be largely empirical in nature or they are scaled up versions of the techniques described in section 9 for fine particle suspensions. In the former case are the most commonly used tests in the industry; they generally represent an attempt to "imitate" a mode of placement or flow of the concrete during production. In the latter case are less common methods that attempt to measure fundamental rheological properties of concrete. In addition, rheological test methods for concrete tend to fall into one of four general categories:

confined flow The material flows under its own weight or under an applied pressure through a narrow orifice. The orifice is defined as an opening roughly three to five times larger than the maximum particle size. Because coarse aggregates are often of the order of 30 mm, the orifice must typically be 90 mm to 150 mm in diameter. Confined flow methods include *flow cone, filling ability* devices, *flow test* through an opening and the *Orimet apparatus.*

free flow The material either flows under its own weight, without any confinement or an object penetrates the material by gravitational settling. Free flow methods include *slump, modified slump, penetrating rod* and *turning tube viscometer.*

vibration The material flows under the influence of applied vibration. The vibration is applied by using a vibrating table (e.g., Ve-Be time and remolding test), dropping the base supporting the material (*DIN slump cone test*), an external vibrator (e.g., *LCL apparatus*) or an internal vibrator (e.g., *settling method*).

rotational rheometers The material is sheared between two parallel surfaces, one or both of which are rotating. These tests are analogous to rheometers described in section 9, except in this case the gap between surfaces must be scaled up to reflect the much larger dimensions of the concrete particles. Rotational rheometers include *BTRHEOM, CEMAGREF, two-point* or *Tattersall, IBB*, and *BML.*

Separate glossaries of rheological terms and test methods are provided below. For more detailed summaries of the numerous rheological tests used throughout the concrete industry, including empirical tests that are widely implemented, see Ferraris (1999) in the list of primary sources.

3.9.1 Glossary of Rheological Terms

Much of the rheological work on concrete and other cementitious materials has, historically, been directed toward the practical exploitation of the material and, as a result, numerous terms are in common use that are unique to the concrete, mortar and cement industries. The most frequently encountered rheological terms are defined here.

consistency The relative *mobility* or ability of freshly mixed concrete or mortar to *flow*; the usual measurements are *slump* for concrete, flow for mortar or grout, and penetration resistance for neat cement paste. (see: *normal consistency, plastic consistency, wettest stable consistency*)

consistency factor A measure of grout *fluidity*, roughly analogous to viscosity, that describes the ease with which grout may be pumped into pores or fissures; usually a laboratory measurement in which *consistency* is reported in degrees of rotation of a torque viscometer in a specimen of grout.

consolidation The process of inducing a closer arrangement of the solid particles in freshly mixed concrete or mortar, during and after placement until setting, by the reduction of voids. Consolidation is accomplished by vibration, centrifugation, rodding, tamping or some combination of these actions. This term is also applicable to similar manipulation of other cementitious mixtures, soils, aggregates or the like.

finishing Leveling, smoothing, consolidating and otherwise treating the surfaces of fresh or recently placed concrete or mortar to produce the desired appearance and service.

impending slough *Consistency* of a shotcrete mixture containing the maximum amount of water such that the product will not *flow* or sag after placement.

mobility The ability of fresh mixed concrete or mortar to *flow*.

normal consistency (1) The degree of wetness exhibited by a freshly mixed concrete, mortar, or neat cement grout when the *workability* of the mixture is considered acceptable for the purpose at hand. (2) The physical condition of neat cement paste as determined with the *Vicat apparatus* in accordance with a standard test method (e.g., ASTM C 187).

plastic consistency Condition of freshly mixed cement paste, mortar or concrete such that *deformation* will be sustained continuously in any direction without rupture.

slump A measure of *consistency* of freshly mixed concrete, mortar or stucco equal to the subsidence measured to the nearest 5 mm (1/4 in) of the molded specimen after removal of the *slump cone.*

wettest stable consistency The condition of maximum water content at which cement grout and mortar will adhere to a vertical surface without sloughing.

workability [placeability] That property of freshly mixed concrete or mortar that determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished.

3.9.2 Glossary of Test Methods

BML Commercial *rotational rheometer* derived from the *two-point test.* The principle of operation is identical to the two-point test, but the shape of the vane has been modified. The vane is as shown in Figure 10(c).

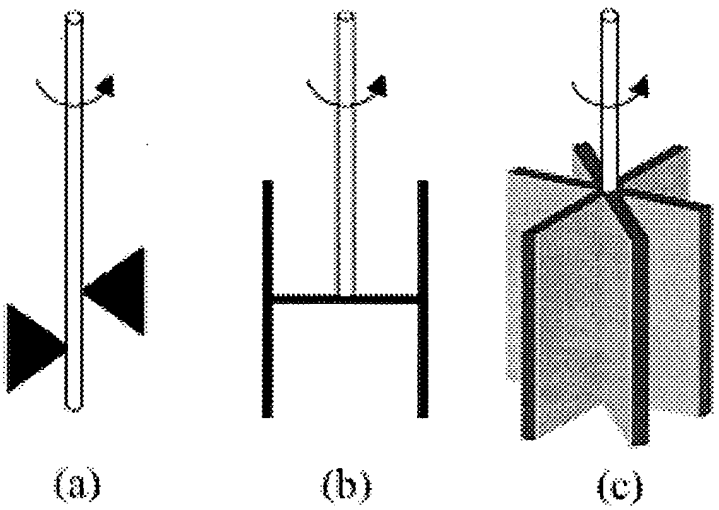

Fig. 10. Various vane geometries used in concrete rheometers: (a) two-point test or Tattersall, (b) IBB, (c) BML.

BTRHEOM Commercial *parallel plate* concrete *rheometer*. Measurements can be performed with and without applied vibration.

CEMAGREF Coaxial *rotational rheometer* originally developed for testing fluid lava. It has been occasionally employed to test concrete. Only one prototype currently exists.

DIN slump cone test A vibration method. A variation of the *slump cone test* in which the cone is placed on a metal sheet. After filling the cone with concrete, it is lifted and the metal support sheet is raised on one side and dropped from a pre-established height (usually about 100 mm) a specified number of times. The spread of the concrete is measured. This standard test is described in DIN 1045.

filling ability *Confined flow method* measuring the ability of concrete to *flow* into a predefined form. Several different molds are used: U-shaped and L-shaped are the most common. In both cases the concrete is forced by gravity to flow into and fill the mold. The volume occupied by the concrete at the end of the test is a measure of the ability of the concrete to flow or its filling ability.

flow cone [V-funnel cone] *Confined flow method* consisting in filling a funnel with concrete or cement paste and determining the time for the material to *flow* out through the orifice. This time is a measure of the material's ability to flow. There are several types of funnel, some with round and others with parallel piped orifice and upper opening.

flow test Used in accordance with ASTM C1362. This test measures the *flow* of concrete or mortar into a perforated tube. This method is applicable for concrete with coarse aggregates less than 37.5 mm in diameter. The instrument consists of a hollow perforated tube that is inserted in the concrete sample, after which the material is allowed to flow into the hollow tube. The height of the concrete in the hollow tube is considered a measure of the *consistency* of the concrete.

IBB Commercially available *rotational rheometer*. It is derived from the *two-point test*. The principle of operation is identical, but the vane shape has been modified, and the vane moves in a planetary motion and on its axis. The vane is shaped like the letter H and is shown in Figure 10(b).

LCL apparatus A *vibration method*. The concrete is poured behind a gate in a large parallel piped container. The gate is opened and the vibrator is turned

on. The time for the concrete to *flow* and occupy the whole container is measured. A longer time suggests a lower ability of the concrete to flow.

modified slump test Modification of the *slump test* described in ASTM C143. It permits the measurement of the rate at which the concrete is slumping, which gives an estimate of the concrete *plastic viscosity*. This test was developed at NIST, but is not currently a standard method (see Ferraris (1999) in primary sources).

Orimet apparatus *Confined flow method* instrument consisting of a tube 600 mm in length that is closed at the bottom by a removable trap door. The time for the concrete to *flow* through the tube once the trap is released is determined. This time is a measure of the ability of concrete to flow.

penetrating rod *Free flow method* measuring the distance a rod of fixed mass can penetrate a concrete sample. It is a crude determination of whether the *yield stress* of the concrete is higher or lower than a predefined value. It is used to monitor concrete at the job site. A specific application of this test is the *Vicat apparatus*.

settling method [Fritsch test] A *vibration method*, this test measures the capability of concrete to *consolidate* under vibration. Concrete is placed in a container with an internal vibrator. The time to obtain full consolidation is measured. The full consolidation is determined when the surface of the concrete no longer moves.

slump cone test *Free flow method* in which a truncated metal cone, open at both ends and sitting on a horizontal surface, is filled with concrete and lifted gradually. The *slump* of the concrete is measured. This standard test is described in ASTM C143.

turning tube viscometer *Free flow method* consisting of a tube 60 mm in diameter and 800 mm long that can be filled with cement paste or mortar. A ball is dropped into the fluid and its velocity is measured between two points 370 mm apart. Using the Stokes equation, the viscosity can be calculated.

two-point test [Tattersall rheometer] First commercially available *rotational rheometer* for concrete. It is the first attempt to *shear* concrete at different rates and to measure the induced *stress*. It consists of a bucket filled with concrete and a vane, shown in Figure 10(a), that rotates at controlled speeds. The torque generated during rotation is measured.

Ve-Be time [remolding test] Measures the ability of concrete to change shape under vibration. Concrete is placed in a *slump cone*. After the cone is lifted away, the time it takes for the concrete to remold itself into a cylinder while under vibration is measured.

Vicat apparatus A *free flow method*, the Vicat apparatus is a penetration device used in the testing of hydraulic cements and similar materials. The full description of this instrument and the correct procedure to determine the *normal consistency* of cement is described in ASTM C187.

3.10 Units and Symbols

3.10.1 Rheometric Units

All units should conform to the International System of Units (SI) as defined by the National Institute of Standards and Technology.[1] The use of CGS and other non-SI units is discouraged. For convenience, SI units are shown in Table 1 in association with their common non-SI equivalents (including decimal submultiples and conversion factors where appropriate). Table 2 shows the SI-derived units with their underlying base units.

Table 1. SI and equivalent rheometric units.

Quantity	SI Units	Equivalent CGS Units
viscosity	$Pa \cdot s$	10 P (poise) or 1000 cP (centipoise)
kinematic viscosity	$m^2 \cdot s^{-1}$	10^4 St (stoke) or 10^6 cSt (centistoke)
shear stress	Pa	$0.1\ dyn \cdot cm^{-2}$
strain	unitless	
shear rate	s^{-1}	s^{-1}
modulus	Pa	$0.1\ dyn \cdot cm^{-2}$
compliance	Pa^{-1}	$10\ cm^2 \cdot dyn^{-1}$
frequency	Hz	
angular frequency	$2\pi f$	
phase angle	rad	

[1] B.N. Taylor, *Guide for the Use of the International System of Units (SI)*, NIST Special Publication 811, 2nd Edition, National Institute of Standards and Technology, U.S. Government Printing Office, Washington, DC, 1995.

Table 2. SI derived units expressed in terms of SI base units.

Symbol	Special Name	Other SI Units	SI Base Units
Pa	Pascal	$N \cdot m^{-2}$	$kg \cdot m^{-1} \cdot s^{-2}$
Hz	Hertz		s^{-1}
rad	radian		$m \cdot m^{-1} = 1$

3.10.2 List of Symbols

σ	shear stress
σ_n	normal stress
σ_y	yield stress
γ	strain
$\dot{\gamma}$	shear rate [rate of shear strain]
De	Deborah number
Pe	Peclet number
Re	Reynolds number
η	coefficient of viscosity [viscosity]
η_{app}	apparent viscosity
η_{diff}	differential viscosity
η_{∞}	infinite shear viscosity
η_{inh}	inherent viscosity
$[\eta]$	intrinsic viscosity
η_{red}	reduced viscosity
η_r	relative viscosity
η_s	viscosity of suspending medium or solvent
η_{sp}	specific viscosity
η_0	zero shear viscosity
ν	kinematic viscosity
ϕ	fluidity
G	shear modulus
*G**	complex shear modulus
G'	shear storage modulus
G''	shear loss modulus
$\|G^*\|$	absolute shear modulus
η^*	complex viscosity
η'	dynamic viscosity (real component of the complex viscosity)
η''	imaginary component of the complex viscosity

J	shear compliance
J^*	complex shear compliance
J'	shear storage compliance
J''	shear loss compliance
$\|J^*\|$	absolute shear compliance
τ	relaxation time, retardation time
σ_0	stress amplitude
γ_0	strain amplitude
δ	phase angle
ω	angular frequency
f	frequency

3.11 Bibliography

This bibliography cites sources used in the compilation of this guide. It is not, nor is it intended to be, an exhaustive list of references available on the vast subject of rheology or rheological instrumentation. Nevertheless, it may serve as a good starting point for those who are relatively new to this field or searching for relatively fundamental information.

3.11.1 Primary Sources

American Concrete Institute, *Cement and Concrete Terminology*, ACI 116R-90, ACI Manual of Concrete Practice 2000, Part 1, Farmington Hills, MI.

British Standards Institution, *Glossary of Rheological Terms*, BS 5168:1975.

A.A. Collyer and D.W. Clegg, Editors, *Rheological Measurement*, Chapman and Hall, London, 1998.

J.M. Dealy, "Official Nomenclature for Material Functions Describing the Response of a Viscoelastic Fluid to Various Shearing and Extensional Deformations," *Journal of Rheology*, **39**[1], 253-265 (1995).

C.F. Ferraris, "Measurement of the Rheological Properties of High Performance Concrete: State of the Art Report," *Journal of Research of the National Institute of Standards and Technology*, **104**[5], 461-478 (1999).

A. Kaye, R.F.T. Stepto, W.J. Work, J.V. Alemán and A.Ya. Malkin, "Definition of Terms Relating to the Non-Ultimate Mechanical Properties of Polymers," IUPAC Recommendations 1997, *Pure and Applied Chemistry*, **70**, 701-754 (1998).

3.11.2 Other Sources

H.A. Barnes, "Shear-Thickening ("Dilatancy") in Suspensions of Nonaggregating Solid Particles Dispersed in Newtonian Liquids," *Journal of Rheology*, **33**[2], 329-366 (1989).

M. Bohdanecky and J. Kovár, *Viscosity of Polymer Solutions*, Elsevier, Amsterdam, 1982.

E.C. Bingham, "An Investigation of the Laws of Plastic Flow," *U.S. Bureau of Standards Bulletin*, **13**, 309-353 (1916).

F.R. Eirich, Editor, *Rheology - Theory and Applications*, Vol. 1, Academic Press, NY, 1956; Vol. 3, 1960; Vol. 4, 1967.

J.W. Goodwin, "Rheology of Ceramic Materials," *Ceramic Bulletin*, **69**[10], 1694-1698 (1990).

P.C. Hiemenz and R. Rajagopalan, *Principles of Colloid and Surface Chemistry*, 3rd Edition, Chapter 4, pp. 145-192, Marcel-Dekker, 1997.

R.J. Hunter, "Rheology of Colloidal Dispersions," Chapter 18 in *Foundations of Colloid Science*, Vol. 2, Oxford University Press, NY, 1989.

J. Mewis and A.J.B. Spaull, "Rheology of Concentrated Dispersions," *Advances in Colloid and Interface Science*, **6**, 173-200 (1976).

D. Quemada, "Models for Rheological Behavior of Concentrated Disperse Media under Shear", pp. 571-582 in *Advances in Rheology*, Vol. 2: Fluids, Universidad Nacional Autonoma de Mexico, Mexico, 1984.

H.N. Stein, "Rheological Behavior of Suspensions," pp. 3-48 in *Encyclopedia of Fluid Mechanics*, Vol. 5: Slurry Flow Technology, Gulf Publishing Company, Houston, 1986.

J.R. Van Wazer, J.W. Lyons, K.Y. Kim, and R.E. Colwell, *Viscosity and Flow Measurement - A Laboratory Handbook of Rheology*, Interscience Publishers, New York, 1963.

R.W. Whorlow, *Rheological Techniques*, Ellis Horwood Ltd., Chichester, 1980.

A.A. Zaman, *Techniques in Rheological Measurements: Fundamentals and Applications*, Instructional Module, NSF Engineering Research Center for Particle Science and Technology, University of Florida, Gainesville, 1998.

Acknowledgments

American Concrete Institute, International Union of Pure and Applied Chemistry (IUPAC), and The Society of Rheology (Journal of Rheology) have kindly granted permission to use or adapt their published definitions in

developing the current document. Their publications are fully cited in the list of primary sources shown above. Extracts from BS 5168:1975 are reproduced with the permission of British Standards Institution under license number PD\1999 0296. Complete copies of the standard can be obtained by post from BSI Customer Services, 389 Chiswick High Road, London W4 4AL.

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EXHIBIT D

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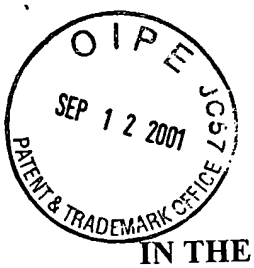

PATENT
Atty. Docket No. INK-006
(2108/13)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICANTS:	Albert *et al.*		
SERIAL NUMBER:	09/140,862	ART UNIT:	2778
FILING DATE:	August 27, 1998	EXAMINER:	David L. Lewis
TITLE:	Color Electrophoretic Displays		

BRIEF ON APPEAL

BOX AF
Commissioner for Patents
Washington, D.C. 20231

Sir:

This is an appeal from the final rejection of claims 1-10 mailed by the patent office on April 9, 2001. A Notice of Appeal for this application was received by the United States Patent and Trademark Office on June 11, 2001.

A one-month extension of time up to and including September 12, 2001, for filing an Appeal Brief is respectfully requested. It is Appellants' understanding that September 11, 2001, will be considered as a "federal holiday within the District of Columbia" under 35 U.S.C. § 21(b). A petition for the extension of time and appropriate fee are being submitted concurrently herewith. Also submitted herewith is an Appendix presenting the claims on appeal, Exhibit A presenting evidence of the real party in interest, and Exhibit B presenting evidence of the meaning of relevant terms. The Appeal Brief, Appendix, and Exhibits A-B are submitted in triplicate in accord with 37 C.F.R. § 1.192(a).

(1) Real Party in Interest

The real party in interest in the above-identified patent application is E Ink Corporation. Assignments perfecting E Ink Corporation's interest in this application were submitted to the

U.S. Patent and Trademark Office on March 11, 1999 and June 9, 1999. Copies of the Assignments, the Notices of Recordation of Assignment Document, and the PTO-stamped Recordation Form Cover Sheets are attached hereto as Exhibit A.

(2) Related Appeals and Interferences

To the best of the Appellants knowledge, there are currently no related interferences. Appeals have been taken in United States Patent Application Serial No. 09/140,846, filed August 27, 1998 (Appeal Brief filed August 21, 2000), and in United States Patent Application Serial No. 09/140,792, filed August 27, 1999 (Appeal Brief filed September 10, 2001), and may be considered related to the instant appeal.

(3) Status of Claims

The claims on appeal are claims 1-10 of the instant application. Claims 1, 2 and 6 remain rejected under 35 U.S.C. §103(a) over United States Patent No. 3,756,693 to Ota et al. ("Ota '693") and Japanese patent abstract publication number JP 01086116 by Naoyuki ("Nayouki")[1]. Claims 3-5 and 7-10 remain rejected under 35 U.S.C. § 103(a) over Ota '693 in view of Naoyuki and United States Patent No. 3,870,517 to Ota et al. ("Ota '517"). The claims on appeal appear in the Appendix attached hereto.

(4) Status of Amendments

In the Final Office Action mailed from the U.S. Patent and Trademark Office on April 9, 2001, claims 1, 2 and 6 were rejected under 35 U.S.C. §103(a) as unpatentable over Ota '693 and Naoyuki. Claims 3-5 and 7-10 were rejected under 35 U.S.C. § 103(a) as unpatentable over Ota '693 in view of Naoyuki and Ota '517. Appellants submitted a Notice of Appeal to the United States Patent and Trademark Office, which was received on June 11, 2001.

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[1] Appellants note that in a teleconference conducted on September 15, 2000, the Examiner confirmed that JP 01086116 was miscited by the Office as JP 401086111A. Appellants further note that the reference continues to be miscited in Patent Office communications subsequent to the September 15, 2000, conversation. Therefore, Appellants treat references to JP 401086111A as references to JP 01086116.

(5) Summary of Invention

Appellants appeal the rejection of the invention claimed by claims 1-10. As defined by appealed claims 1, 2 and 6, Appellants invention relates to an electrophoretic display comprising at least one capsule (20), the capsule (20) includes one or more particles (50) and a suspending fluid (25), and at least two electrodes (30, 40) positioned adjacent the capsule. See, e.g., Specification, page 11, lines 22-27 and Figures 1A-1C. The capsule comprises at least a first particle having a first optical property and a first electrophoretic mobility. See, e.g., Specification, page 19, lines 23-26, and Figures 6, 7A-7B, 8A-8D, and 9A-9C. The application of an electric field to the capsule (20) by the electrodes (30, 40) causes the capsule (20) to change visual state in response to the optical properties and electrophoretic mobilities of the particles (e.g., R, G and B of Figures 6, 7A-7B, 8A-8D, and 9A-9C). Where the display has a first particle (e.g., B of Figures 7A -B) with a first electrophoretic mobility and a second particle (e.g., R or G of Figures 7A -B) with a second electrophoretic mobility, the first and the second electrophoretic mobility are, for example, substantially non-overlapping. See, e.g., Specification, page 20, lines 3-20, and Figures 7A-7B.

As defined by appealed claims 5, 8 and 9, Appellants invention also relates to an electrophoretic display comprising at least one capsule (20) having at least one particle (50) and a suspending fluid (25) and at least two electrodes (30, 40) disposed adjacent the at least one capsule (20). See, e.g., Specification, page 11, lines 22-27, and Figures 1A-1C. The suspending fluid may be dyed a color. See, e.g., Specification, page 12, line 14. A voltage potential applied to one of the electrodes causes particles to migrate within the capsule, changing the visual state of the capsule. See, e.g., Specification, page 18 lines 18-26. The at least one particle can have, for example, an optical property matching an optical property of one of the at least two electrodes. See, e.g., Specification, page 13, lines 20-21. The at least one particle may be, for example, a substantially white particle. See, e.g., Specification, page 19, line 7.

As defined by appealed claim 3, Appellants invention relates to an electrophoretic display comprising at least one capsule (20), the capsule (20) includes at least one red particle (R), at least one blue particle (B), and at least one green particle (G), a suspending fluid (25), and at least two electrodes (32, 34) positioned adjacent the capsule (20). See, e.g., Specification, page

20, lines 3-20, and Figures 6, 7A-7B, 8A-8D, and 9A-9C. The capsule (20) comprises at least a first particle having a first optical property and a first electrophoretic mobility and a second particle having a second optical property and a second electrophoretic mobility. See, e.g., Specification, page 19, lines 23-26. The application of an electric field to the capsule (20) by the electrodes (32, 34) causes the capsule (20) to change visual state in response to the optical properties and electrophoretic mobilities of the particles (R, G, and B). See, e.g., Specification, page 20, lines 3-20, and Figures 6, 7A-7B, 8A-8D and 9A-9C.

As defined by appealed claims 4 and 7, Appellants' invention relates to the electrophoretic displays described above in connection to claims 1 and 6, respectively, in which the suspending fluid is substantially transparent. See, e.g., Specification, page 12, line 12-13.

As defined by appealed claim 10, Appellants invention relates to an electrophoretic display comprising at least one capsule (20) containing a suspending fluid (25) and at least one white particle, disposed adjacent the capsule 20 and spaced apart from one another are electrodes that are cyan-colored (42), magenta-colored (44), yellow-colored (46), and white (48) electrodes. See, e.g., Specification, page 19, lines 5-8, and Figures 5A and 5B. A voltage potential applied to the various electrodes(42, 44, 46, and 48) causes the particles (55) to migrate and the capsule (20) to appear in different colors. See, e.g., Specification, page 19, lines 9-22, and Figures 5A and 5B.

(6) Issues

1. The first issue presented for appeal is whether appealed claims 1, 2 and 6 are patentable under 35 U.S.C. § 103(a) over Ota '693 in view of Naoyuki.

2. The second issue presented for appeal is whether appealed claims 5, 8 and 9 are patentable under 35 U.S.C. § 103(a) over Ota '693 in view of Naoyuki and Ota '517.

3. The third issue presented for appeal is whether appealed claim 3 is patentable under 35 U.S.C. § 103(a) over Ota '693 in view of Naoyuki and Ota '517.

4. The fourth issue presented for appeal is whether appealed claims 4 and 7 are patentable under 35 U.S.C. §103(a) over Ota '693 in view of Naoyuki and Ota '517.

5. The fifth issue presented for appeal is whether appealed claim 10 is patentable under 35 U.S.C. §103(a) over Ota '693 in view of Naoyuki and Ota '517.

6. Although Appellants believe that the above-identified two issues correspond to all of the pending rejections, Appellants also appeal any other bases for rejection of the pending claims which were not explicitly stated in the Final Office Action but which may be regarded as still pending.

(7) Grouping of Claims

The rejected claims 1-10 **do not** stand or fall together.

Claims 1, 2 and 6 stand or fall together.

Claims 5, 8 and 9 stand together

Claim 3 stands alone.

Claims 4 and 7 stand together.

Claim 10 stands alone.

(8) Appellants' Argument

Appellants believe that there are no outstanding claim rejections under 35 U.S.C. §112, first or second paragraph. The following arguments address each of the issues presented for appeal. Appellants respectfully request reversal of the final rejections of claims 1-10 under 35 U.S.C. § 103(a) because the references asserted by the Examiner do not teach or fairly suggest the inventions of Appellants' claims 1-10. Further, the references, evidence and arguments asserted by the Examiner fail to establish a *prima facie* case of obviousness against Appellants' claims 1-10.

8.1 Claims 1, 2 and 6 are patentable over Ota '693 in view of Naoyuki

Appellants respectfully request that the final rejection of claims 1, 2, and 6 under 35 U.S.C. § 103(a) be reversed because the references asserted by the Examiner do not enable the ordinary artisan to produce Appellant's invention as a whole. It is well settled that a prior art reference must place any allegedly disclosed matter in the possession of one of ordinary skill in the art such that it is capable of being put into practical operation. See, e.g., Seymour v. Osborn, 78 U.S. 516, 555, 20 L.Ed. 33, 42 (1870); In re Brown, 51 C.C.P.A. 1254, 1259, 329 F.2d 1006, 1011 (CCPA 1964). Further, to establish obviousness requires a showing that the prior art provides every limitation of a claim and the invention as a whole. See Graham v. John Deere Co., 383 U.S. 1, 17-18, 86 S.Ct. 684, 695-96, 148 U.S.P.Q. 459, 467 (1966); In re Royka, 490 F.2d 981, 985, 180 USPQ 580 (CCPA 1974); see also MPEP §§ 2142, 2143 (7th Ed., July 1998). As a result, a reference, or combination of references, that does not enable one of ordinary skill in the art to practice every limitation of a claim can not render that claim obvious. See, e.g., MPEP § 2121.01 (7th Ed., July 1998). Enablement of a limitation requires a description that: "enable[s] any person skilled in the art to which it pertains ... to make and use the same." 35 U.S.C. § 112, 1st paragraph. Accordingly, a combination of references, in view of knowledge in the art, cannot render a claim limitation obvious if there is no description of how to make and use said limitation.

Appellants respectfully submit that, either alone or in combination, Ota '693 and Naoyuki fail to enable one of ordinary skill in the art to practice the "encapsulation" limitation of:

> [a]n electrophoretic display comprising: at least one capsule containing a suspending fluid and at least [one] particle

required by Applicants' claims 1, 2 and 6. As a result, Naoyuki cannot be properly combined with Ota '693 to produce Appellants' claimed invention as a whole because these references do not to provide any teaching that would enable one of ordinary skill in the art to modify Ota '693 with Naoyuki to provide the "capsule containing a suspending fluid and at least [one] particle" as set forth in Appellants' claims. Accordingly, the modification of Ota '693 with Naoyuki to produce Appellants' claims 1, 2 and 6 is improper, and the rejection of claims 1, 2 and 6, under 35 U.S.C. § 103(a) should not be maintained.

More particularly, Ota '693 does not mention capsulated particles or even suggest, "at least one capsule containing a suspending fluid and at least [one] particle," as required by Appellants' claims. Appellants maintain that enclosing particles between two electrodes does not constitute encapsulation of particles as that term is used in the application because Appellants' capsule is a structure and claim element distinct from the electrodes. Specifically, in relevant part, Appellants' claims 1, 2 and 6 require:

> An electrophoretic display comprising:
> at least one capsule..; and
> at least two electrodes disposed adjacent [said] capsule;

(emphasis added). Appellants thus submit that Ota '693 does not disclose a capsule, but rather unencapsulated particles disposed between electrodes. (See, e.g., Ota '693, col. 2, lines 21–41, see also Figs. 1a, 2-6). Accordingly, Ota '693 does not disclose a "capsule" that is separate and distinct from the electrodes because in Ota '693 the electrodes themselves are the walls that enclose the electrophoretic material. As a result, Ota '693 does not disclose "electrodes disposed adjacent [said] capsule" as set forth in Appellants' claims 1, 2 and 6. Moreover, the Final Office Action of April 9, 2001, at pages 2-3, admitted that, "...Ota ['693] is silent as to the display particles being within a capsule, the type that may be considered in plurality." Accordingly, Ota '693 does not disclose or suggest the "encapsulation" limitation of Appellants' claims 1, 2 and 6.

Naoyuki does not cure the deficiencies of Ota '693 because Naoyuki merely mentions capsulated particles but provides no enabling description of making or using the limitation of, "at least one capsule containing a suspending fluid and at least [one] particle," as set forth in Appellants' claims 1, 2 and 6. Specifically, Naoyuki reads in its entirety:

> ABSTRACT: PURPOSE: To facilitate the sealing treatment of a dispersion system and to assure a good electrophoretic display operation by adopting a technique to previously microcapsulate the dispersion system.
>
> CONSTITUTION: The dispersion system 5 is previously microcapsulated and the microcapsules 3 are disposed between electrodes for display control. Since the compsn. of the microcapsulated dispersion system 5 are uniformly held and, therefore, the flocculation of the electrophoresis particles or the sticking thereof to electrodes is eliminated

> and the uniform and stable display operation is accomplished. The handling of the dispersion system 5 or the sealing treatment of the dispersion system 5 is greatly improved without adversely affect the dispersion system 5 at the time of assembly. The electrophoretic display device having good characteristics is thus obtd.

Appellants' submit that absent some discussion of how to perform (i.e., make or use) Appellants' above "encapsulation" claim limitation, Naoyuki's mere mention of microencapsulation is simply a suggestion to try capsulated particles. Naoyuki's simple suggestion to try microencapsulation is insufficient to render that Appellants' "encapsulation" limitation obvious because one of ordinary skill in the art would have no reasonable expectation of successfully practicing Appellants' "electrophoretic display comprising: at least one capsule containing a suspending fluid and at least [one] particle."

For example, Naoyuki mentions "adopting a technique to previously microencapsulate," and that the, "microcapsules 3 are disposed between electrodes," but does not provide any description that enables one of ordinary skill in the art to make or use such capsules. Moreover, Naoyuki does not provide any description that enables one of ordinary skill to make or use "at least one capsule containing a suspending fluid and at least [one] particle" as set forth in Appellants' claims 1, 2 and 6. As a result, Appellants submit that claims 1, 2 and 6 are non-obvious because, either alone or in proper combination, Ota '693 and Naoyuki do not enable the above "encapsulation" limitation of these claims. Therefore, Appellants respectfully request reversal of the rejection of claims 1, 2, and 6.

In addition, Appellants submit that Naoyuki is also completely silent on the encapsulation of particles with different optical properties and electrophoretic mobilities. Specifically, Appellants' claims 1 and 2 require:

> An electrophoretic display comprising:
>
> at least one capsule containing a suspending fluid and at least a first particle and a second particle, said first particle having a first optical property and a first electrophoretic mobility and said second particle having a second optical property and a second electrophoretic mobility;

Particles that differ in these properties typically have substantially different surface properties. Particles with different surface properties will have different interactions with the surface of a capsule. As a result, there can be no reasonable expectation that an encapsulation or capsule material suitable for encapsulating particles with one surface property will work to encapsulate particles with different surface properties. Moreover, there can be no reasonable expectation that the behavior of particles with different surface properties will be the same within a capsule as within an unencapsulated medium (e.g., such as the medium of Ota '693). Thus, Naoyuki and Ota '693 do not render Applicants' claims 1 and 2 obvious because one of ordinary skill in the art would not have a reasonable expectation of successfully modifying or combining Ota '693 with Naoyuki to practice as required by these claims a "capsule containing [a] first particle having a first optical property and a first electrophoretic mobility and [a] second particle having a second optical property and a second electrophoretic mobility."

In the final rejection of claims 1, 2 and 6 under 35 U.S.C. § 103(a) over Ota '693 and Naoyuki the Examiner reasserted verbatim his prior conclusion regarding these claims that, "[m]odifying the display as taught by Ota to include capsulized particles is well known and would be obvious to the skilled artisan." (See Final Office Action of April 9, 2001, at page 3; cf. Office Action of August 29, 2000, at page 3). In the Final Office Action of April 9, 2001, the Examiner did not address the arguments made by Appellants in their Response filed January 29, 2001, that the references, in view of the art, lacked any teaching that would enable one of ordinary skill in the art to so modify Ota '693 with Naoyuki. Instead, the Examiner mischaracterized Appellants' arguments and ignored them.

In particular, in the Final Office Action, the Examiner stated,

> The applicant argues Naoyuki et al. fails to teach how to encapsulate the particles in such a display as taught by Ota, however this point is irrelevant given the fact that the claims are not drawn to a process method for making or encapsulating particles of a display, they are merely drawn to a display apparatus. The applicant argues a moot point. Naoyuki's suggestion for encapsulating a display of the type taught by Ota is sufficient basis for the rejection.

(Final Office Action of April 9, 2001 at page 5). Appellants respectfully submit that a failure of a reference to enable a claim limitation is not irrelevant nor argument of a moot point. See e.g.,

Seymour, 78 U.S. at 555, 20 L.Ed. at 42. Although Appellants used the word "how" in their prior arguments, Appellants made clear from the beginning (and by the entire context of their argument) that the issue was how to make and use a claim limitation in accord with 35 U.S.C. § 112.

Furthermore, Appellants submit that the Examiners assertion that, "Naoyuki's suggestion for encapsulating a display of the type taught by Ota is sufficient basis for the rejection," is incorrect as a matter of law to establish either a *prima facie* case of obviousness or to maintain an rejection under 35 U.S.C. § 103(a). Specifically, three criteria must be met to establish a *prima facie* case of obviousness: (1) some suggestion or motivation to modify or combine the references; (2) a reasonable expectation of success; and (3) the combination must teach or suggest all the claim limitations. See Graham, 383 U.S. at 17-18, 86 S.Ct. at 695-96, 148 U.S.P.Q. at 467 ; In re Vaeck, 947 F.2d 488, 493, 20 U.S.P.Q.2d 1438 (Fed. Cir. 1991); see also MPEP § 2142 (7th Ed., July 1998). Accordingly, the Examiner's position that, "Naoyuki's suggestion for encapsulating a display of the type taught by Ota is sufficient basis for the rejection," is in error and on its face indicates the Examiner's basis for rejection of claims 1, 2 and 6 fails to establish a *prima facie* case of obviousness as a matter of law.

Thus, for the reasons described above, Appellants respectfully submit that claims 1, 2 and 6, are novel and nonobvious over Ota '693 in view of Naoyuki because these references, either alone or in proper combination, do not teach, fairly suggest or enable one of ordinary skill in the art to practice every limitation of these claims. Moreover, for the reasons above, Appellants submit that the Examiner has failed to establish a *prima facie* case of obviousness against claims 1, 2 and 6. Therefore, Appellants respectfully request reversal of the rejection of claims 1, 2 and 6.

8.2 Claims 5, 8 and 9 are patentable over Ota '693 in view of Naoyuki and Ota'517

Appellants' respectfully submit that claims 5, 8 and 9 are patentable because Ota '517, Ota '693 and Naoyuki, either alone or in proper combination, do not provide an enabling disclosure of making or using the "encapsulation" limitation of: "at least one capsule containing a suspending fluid and at least [one] particle," as set forth in Appellants' claims 5, 8 and 9, which depend from either claim 1 or 6. To establish obviousness requires a showing that the prior art

provides every limitation of a claim and the invention as a whole. See Graham, 383 U.S. at 17-18, 86 S.Ct. at 695-96, 148 U.S.P.Q. at 467; In re Royka, 490 F.2d at 985; see also MPEP §§ 2142, 2143 (7th Ed., July 1998). Accordingly, Appellants respectfully request reversal of the rejection of claims 5, 8 and 9.

For the reasons described above with respect to claims 1, 2, and 6, Appellants submit that Ota '693 and Naoyuki fail to teach or fairly suggest the above "encapsulation" limitation of Appellants' claims 5, 8 and 9, and that Ota '517 fails to provide this missing teaching. Specifically, Appellants submit that Ota '517's enclosure of particles between two electrodes does not teach or fairly suggest, "at least one capsule containing a suspending fluid and at least [one] particle," because Appellants' capsule is a structure and claim element distinct from the electrodes. Specifically, in relevant part, Appellants' claims 5, 8 and 9 require:

> An electrophoretic display comprising:
> at least one capsule..; and
> at least two electrodes disposed adjacent [said] capsule;

(emphasis added). Appellants thus submit that Ota '517 does not disclose a capsule, but rather unencapsulated particles disposed between electrodes. (See, e.g., Ota '517, col. 2, lines 46-55, see also Figs. 1a-1d, 2a-2b, 3a-3b, 4, and col. 8, lines 3-48, noting that item number 12 is porous to particle passage). Accordingly, Ota '517 does not disclose a "capsule" that is separate and distinct from the electrodes because in Ota '517 the electrodes themselves are the walls that enclose the electrophoretic material. As a result, Ota '517 does not disclose "electrodes disposed adjacent [said] capsule" as set forth in Appellants' claims 5, 8 and 9.

Thus, for the reasons described above, Appellants respectfully submit that claims 5, 8 and 9, are novel and nonobvious over Ota '693 in view of both Naoyuki and Ota '517 because these references, either alone or in proper combination, do not teach, fairly suggest or enable one of ordinary skill in the art to practice every limitation of these claims. Moreover, for the reasons above, Appellants submit that the Examiner has failed to establish a *prima facie* case of obviousness against claims 5, 8 and 9. Therefore, Appellants respectfully request reversal of the rejection of claims 5, 8 and 9.

8.3 Claim 3 is patentable over Ota '693 in view of Naoyuki and Ota'517

Appellants respectfully request that the final rejection of claim 3 under U.S.C. §103(a) be reversed, because the references asserted by the Examiner, either alone or in proper combination, also do not disclose or fairly suggest an electrophoretic display comprising "at least one capsule which includes at least one red, at least one blue and at least one green particle," as required by Appellants' claim 3. In particular, the teachings of Ota '517 are technologically incompatible with the use of red, green, and blue particles. As a result, the use of red, green and blue particles in Ota '517 would either change the basic principle under which the display of Ota '517 operates or render the display of Ota '517 inoperable for its intended purpose. A reference can not be properly modified to render a claim obvious under 35 U.SC. § 103(a) or establish a *prima facie* case of obviousness when such a modification would change the principle of operation of the reference or render it inoperable for its intended purpose. See In re Gordon, 733 F.2d 900, 902, 221 U.S.P.Q. 1125 (Fed, Cir, 1984); In re Ratti, 270 F.2d 810, 813, 123 U.S.P.Q. 349, 352 (CCPA 1959). Accordingly, the modification of Ota '517 in combination with Ota '693 and Naoyuki to produce Appellants' claim 3 is improper, and the rejection of claim 3 under 35 U.S.C. § 103(a) should not be maintained.

In the final rejection of claim 3 under 35 U.S.C. § 103(a) over Ota '693, Naoyuki, and Ota '517, the Examiner reasserted verbatim his prior conclusion that: "Ota (517) demonstrates how the two particles can be three in number and of varying colors...and since the particles can act as the primary image colorant the skilled artisan could obviously choose red, blue, and green as the particle colors." (Final Office Action of April 9, 2001 at page 3; cf. Office Action of August 29, 2000 at page 3). In the Final Office Action of April 9, 2001, the Examiner did not address the arguments made by Appellants in their response dated January 29, 2001, regarding the technological incompatibility of Ota '517 with the use of red, green, and blue particles as defined by Appellants claim 3. The Examiner simply dismissed the technological incompatibility of using of red, green, and blue particles in Ota '517 with a conclusory response that the, "use of particles of varying colors is an obvious design choice and would have been obvious to the skilled artisan". (Final Office Action of April 9, 2001 at page 5).

The teachings of Ota '517 are technologically incompatible with the use of red, green, and blue particles as set forth in claim 3 and nothing in Ota '693 or Naoyuki cures this technological incompatibility. Neither Ota '693 nor Naoyuki suggest the use of red, blue, and green particles as set forth in claim 3. Consequently, the references asserted by the Examiner, either alone or in combination, would not motivate one of ordinary skill in the art to combine and modify these references to produce a display comprising a capsule having red, green, and blue particles as set forth in Appellants' claim 3.

The technological teachings of Ota '517 teach choosing particles that have a photosensitive response to certain colors of light. (See, e.g., Ota '517, col. 3, line 55 to col. 4, line 5; col. 6, lines 33-66). To understand the display disclosure of Ota '517, it is important to realize the difference between a color (i.e., what a human eye perceives) and a color of light (i.e., a discrete, continuous electromagnetic spectrum wavelength range). For example, it is common knowledge that there is no "white color of light," rather the color we see as white is actually a combination of all the visible colors of light. Accordingly, the principle of operation of a photosensitive particle consists of responding to a color of light, not to colors. In contrast, Appellants' claimed invention does not require a photosensitive response on the part of its electrophoretic particles to work.

Specifically, Ota '517 is directed towards a, "photoelectrophoretic color image reproduction panel" (col. 2, lines 43-44) wherein, "[t]he [electrophoretic] material 6 consists of at least three kinds of photosensitive electrophoretic materials 6a, 6b and 6c, the colors of which are cyan, magenta and yellow, respectively, and have photosensitive response to red, green and blue light, respectively," (col. 2, lines 58-63)(emphasis added). The display of Ota '517 operates based on the principle of a photosensitive response to input light by particles that respond to their complementary color of light. For example, Ota '517 discloses that the cyan particles (e.g., item 6a) respond to red light, the magenta particles (e.g., item 6b) respond to green light, and the yellow particles (e.g., item 6c) respond to blue light. One of ordinary skill in the art, upon reading Ota '517, would understand that his particles are cyan, magenta and yellow because these colors are complementary to the light to which the particles are photosensitive. (See, e.g., Ota '517, col. 3, line 52 to col. 4, line 5). Further, the ordinary artisan would understand that Ota

'517's choice of particle color is not open ended, but rather, dictated by the principle of operation of his display, i.e., the need for a photosensitive response to a color of light. As a result, the technological teaching of Ota '517 makes clear that the colors of his particles are not mere design choices; rather, the particle colors are central to the very principle of operation of his display.

Ota '517's teachings of a display using particle colors that are photosensitive to a complementary light color teaches away from, and are technologically incompatible with, red, green and blue particles because there are no colors of light that are complementary to these particle colors. That the technological teaching of Ota '517 are incompatible with red, blue and green particles can be illustrated by the following example. For example, there is no color of light that is complementary to a green particle color. The color complementary to green is magenta. However, there is no color of light that is magenta because the color magenta is actually a combination of light from both the blue and the red portions of the electromagnetic spectrum. As is well know, red and blue are at opposite ends of the visible portion of the electromagnetic spectrum and are separated by at least the green part of the spectrum. Accordingly, if magenta light is input into a display as taught by Ota '517 that has been modified to use red, green and blue particles, there can be no reasonable expectation that the display will work for its intended purpose based on the technological teachings of Ota '517. The so modified display of Ota '517 can not be expected to work because it is not clear which of the red, green and blue particles (if any) will exhibit a photosensitive response to the magenta light which is actually composed of two colors of light, red and blue. Will the green particle respond? What if the input light is just red, does the green particle still respond? What if the input light is just blue, does the green particle still respond? If the green particle responds to just red and just blue light how does the display distinguish between red and blue so that it is not "color blind"? That these questions could not be answered by one of ordinary skill in the art based on the technological teachings of Ota '517 serves to further illustrate that the technological teachings of Ota '517, which rely on a photosensitive response, cannot be modified to use red, green, and blue particles.

Consequently, Ota '517 inherently teaches away from the use of red, green and blue particles as set forth in Appellants' claim 3 because these colors of particles will not work in the

technology taught by Ota '517. Moreover, one of ordinary skill in the art would have no reasonable expectation of successfully using the teachings of Ota '517 with red, green and blue particles and, in fact, would reasonably expect use of red, green and blue particles to render Ota '517 inoperable. As a result, one of ordinary skill in the art having found Ota '517 would have no motive to use its teachings to modify any other reference to have red, green and blue electrophoretic particles, and could not do so, because the teachings of Ota '517 fundamentally will not work with red, green and blue particles. Therefore, claim 3 is non-obvious over the art asserted by the Examiner because the asserted references fail to provide the limitation of, "at least one red particle, at least one blue particle, and at least one green particle," set forth in claim 3 and fail to teach the invention of claim 3 as a whole.

Thus, for the reasons described above, Appellants respectfully submit that claim 3 is novel and nonobvious over Ota '693 in view of Naoyuki and Ota '517 because these references, either alone or in proper combination, do not teach or suggest the limitation of, "wherein said capsule contains at least one red particle, at least one blue particle, and at least one green particle," required by Appellants' claim 3. Moreover, for the reasons above, Appellants submit that the Examiner has failed to establish a *prima facie* case of obviousness against claim 3. Therefore, Appellants respectfully request reversal of the rejection of claim 3.

8.4. Claims 4 and 7 are patentable over Ota '693 in view of Naoyuki and Ota '517

Appellants respectfully request that the final rejection of claims 4 and 7 under 35 U.S.C. § 103(a) be reversed because the references asserted by the Examiner can not be properly combined to disclose or fairly suggest an electrophoretic display with a "suspending fluid that is substantially transparent" as required by Appellants' claim 4 and 7. Rather, the Ota '517 reference relied on by the Examiner as disclosing a transparent suspending fluid actually teaches away from use of such a fluid in an electrophoretic display. There can be no suggestion to combine a reference with another if the reference teaches away from the combination. See Tec Air, Inc. v. Denso Mfg. Michigan, Inc., 192 F.3d 1353, 1359-60, 52 U.S.P.Q.2d 1294 (Fed. Cir. 1999); In re Fine, 837 F.2d 1071, 1075, 5 U.S.P.Q. 1596, 1599 (Fed. Cir. 1988). As a result, there is nothing in the cited references that would suggest to one of ordinary skill in the art to combine a transparent suspending fluid with an electrophoretic display to produce the invention

of claims 4 and 7. In addition, the Examiner has provided no facts or arguments to show that the nature of the problem or the knowledge of one of ordinary skill in the art would suggest the combination of Ota '517 with Ota '693 and Naoyuki. Absent a suggestion in the prior art to combine references, a rejection under 35 U.S.C. § 103(a) based on the combined references cannot be maintained. See In re Dembiczak, 175 F.3d 994, 999, 1000, 50 U.S.P.Q.2d 1614, (Fed. Cir. 1999)(abrogated in part on other grounds). Accordingly, the combination of Ota '517 with of Ota '693 and Naoyuki to suggest Appellants' invention is improper, and do not establish a *prima facie* case of obviousness against claims 4 and 7. Thus, the rejection of claims 4 and 7 under 35 U.S.C. § 103(a) should be reversed.

In the final rejection of claims 4 and 7 under 35 U.S.C. § 103(a) over Ota '693, Naoyuki, and Ota '517, the Examiner reasserted verbatim his prior conclusion that: "[a]s in claims 4 and 7, Ota (517) teaches of a suspending fluid being transparent, column 4 lines 15-22, wherein colorless obviously implies transparent, column 1 lines 20-25." (Final Office Action of April 9, 2001 at page 3; cf. Office Action of August 29, 2000 at page 3). The Examiner did not address Appellant's prior argument with respect to this ground for rejection of claims 4 and 7 except to conclude, "Applicant's arguments filed 1/29/01 have been fully considered but they are not persuasive." (Final Office Action of April 9, 2001, at page 5).

Appellants respectfully submit that Ota '517 cannot be properly combined with Ota '693 and Naoyuki to reject claims 4 and 7 under 35 U.S.C. § 103(a) because Ota '517 teaches away from claims 4 and 7 as a whole. A reference "teaches away" when one of ordinary skill in the art, on reading the reference, would be discouraged from following the path set forth by the applicant, or would be led in a divergent direction from the path taken by the applicant. See Tec Air, 192 F.3d at 1359-60; In re Fine, 837 F.2d at 1075. A reference can discourage an artisan from following an applicant's path by indicating the claimed combination would not work. Id. In particular, the passage of Ota '571 at column 4, lines 15-22, cited by the Examiner to support his conclusion does not suggest use of a transparent suspending fluid because this passage discloses that a colorless suspending fluid will not work with the teachings of Ota '517.

Specifically, Ota '517 at col. 4, lines 15-22, states:

> at both electrodes 8 and 9, one can observe a positive color image at the electrode 8 and a negative color image at the electrode 9. The material 6 and the suspending medium 7a both act as colorant in the reproduced image. If the suspending medium 7a is colorless, both of the areas subjected to black light or white light will have the same color, that is, a black color at both electrodes 8 and 9 in FIG. 1c.

(emphasis added). Far from suggesting a transparent suspending medium, this passage disclsoes that a colorless suspending medium will not work because if the fluid is colorless both black and white light have the same color in the image, i.e., there will be no contrast, the image will be black. Accordingly, Ota '517 at col. 4, lines 15-22, leads one of ordinary skill in the art away from the idea of combining a transparent suspending fluid in an electrophoretic display by teaching that this combination renders his electrophoretic display inoperable.

Similarly, the passage of Ota '517 at column 1, lines 20-25, cited by the Examiner does not provide a suggestion to combine a transparent suspending fluid with an electrophoretic display. Instead, the entire content of Ota '517 leads one of ordinary skill in the art in a direction divergent to that of claims 4 and 7 by focusing on colored suspending media. Specifically, Ota '517 at col. 1, lines 20-36, states:

> According to these prior art methods, charged particles in a colorless suspending medium are transported to the surface of an electrode so as to reproduce a pattern corresponding to that of an input light image. The visible color image can be obtained by removing the electrode from the surface of the suspension, so that the suspension can not be enclosed in a housing. The particles act as the primary image colorant but the suspending medium does not because it is not colored. That is, the prior art does not seek to bring about a variation in the optical reflective property of a suspension itself due to a change in the spatial distribution of photosensitive particles in the suspension. Therefore, the prior art relates essentially to the reproduction of a permanent visible image but not to a changeable color display system.

(emphasis added). There is nothing in this passage to motivate or suggest the selection and use of the mentioned colorless suspending medium in an electrophoretic display to produce Appellants' claimed combination. On the contrary, the entire context of the remainder of Ota '517 teaches away from a colorless suspending medium by focusing exclusively on use of

colored suspending media for electrophoretic displays. See, e.g., col. 1, lines 44-47 (disclosing "photosensitive electrophoretic materials ... suspended in a white colored suspending medium"); col. 7, lines 18-21 (teaching "colored suspending medium 7a"); col. 8, lines 57-59 (teaching "colored suspending medium 7c"); col. 9, lines 50-52 (stating "[t]he electrophoretic suspension layer in accordance with the present invention having a white suspending medium"). As a result, there is no suggestion or motivation in Ota '517 to combine his mention of a colorless suspending medium with either Ota '693 or Naoyuki to produce the invention of Appellants' claims 4 and 7. Furthermore, the Examiner has provided no facts or arguments to show that the nature of the problem or the knowledge of one of ordinary skill in the art suggested the combination of Ota '517 with Ota '693 and Naoyuki. Accordingly, absent Appellants' application, there is no motivation to combine Ota '517 with either Ota '693 or Naoyuki to produce either claim 4 or 7.

Thus, for the reasons described above, Appellants respectfully submit that claims 4 and 7 are novel and nonobvious over Ota '693 in view of Naoyuki and Ota '517 because these references, either alone or in proper combination, do not teach or suggest an, "electrophoretic display ... wherein said suspending fluid is substantially transparent," as required by claims 4 and 7. Moreover, for the reasons above, Appellants submit that the Examiner has failed to establish a *prima facie* case of obviousness against claims 4 and 7. Therefore, Appellants respectfully request reversal of the rejection of claims 4 and 7.

8.5. Claim 10 is patentable over Ota '693 in view of Naoyuki and Ota'517

Appellants respectfully request that the final rejection of claim 10 under 35 U.S.C. §103(a) be reversed, because Ota '693, Naoyuki and Ota '517, either alone or in proper combination, do not teach or fairly suggest an electrophoretic display having colored electrodes as claimed in Appellants' claim 10. To establish obviousness, all the claim limitations must be taught or suggested. See Graham, 383 U.S. at 17-18, 86 S.Ct. at 695-96, 148 U.S.P.Q. at 467; In re Royka, 490 F.2d at 985; see also MPEP § 2142 (7th Ed., July 1998). Claim 10 defines an electrophoretic display comprising at least one capsule containing a suspending fluid and at least one white particle, electrodes that are cyan-colored, magenta-colored, yellow-colored, and white are disposed adjacent the capsule and spaced apart from one another.

Appellants submit that claim 10 is non-obvious because Ota '693, Naoyuki, and Ota '517, do not teach or fairly suggest colored electrodes or the use of a plurality of electrodes of differing colors as required by claim 10. Specifically, Appellants' claim requires, in part:

> An electrophoretic display comprising...a cyan-colored electrode disposed adjacent said capsule; a magenta-colored electrode disposed adjacent said capsule ...a yellow-colored electrode disposed adjacent said capsule...and a white electrode adjacent said capsule.

The electrophoretic display of Appellants independent claim 10 thus comprises "colored electrodes" whereby the electrodes themselves are colored, not simply electrodes that appear colored because they are viewed through a color overlay. However, the references asserted by the Examiner describe only colored overlays or other colored structure that are not electrodes. Accordingly, the combination of Ota '517, Ota '693 and Naoyuki does not suggest the colored electrodes of Appellants' claim 10, nor establish a *prima facie* case of obviousness against this claim. Thus, the rejection of claim 10 under 35 U.S.C. § 103(a) should be reversed.

In the final rejection of claim 10 under 35 U.S.C. § 103(a) over Ota '693, Naoyuki, and Ota '517, the Examiner reasserted verbatim his prior argument that reads, in relevant part:

> As in claim 10, Ota (693) in view of Naoyuki teaches of the invention as applied to claims 1-9 above, including the particle capsulized multicolored electrophoretic display whose particles have different mobilities according to the voltage bias on the colored coated electrodes. Further, Ota (517) teaches of particles of various colors, including cyan, magenta, yellow, and white, while also teaching of colored electrodes used to hide particles in a particular voltage-bias display state, column 9 lines 1-37.

(Final Office Action of April 9, 2001 at page 4; cf. Office Action of August 29, 2000 at page 4)(emphasis added). In the Final Office Action of April 9, 2001, the Examiner did not address the arguments made by Appellants in their response dated January 29, 2001, regarding the distinction and structural difference between a color overlay and colored electrodes as set forth in Appellants claim 10. The Examiner dismissed these distinctions and differences with a conclusory response, "Further the use of particles of varying colors is an obvious design choice and would have been obvious to the skilled artisan for the purpose of providing a color display, wherein a variety of color electrode and particle color schemes can be chosen". (Final Office Action of April 9, 2001 at page 5). However, Appellants submit that not only do the asserted

references fail to anywhere describe a colored electrode, but also that the Examiner's argument mischaracterizes the references and interprets relevant terms in a manner that does not comport with the accepted usage of the English language.

Specifically, Ota 517 fails to teach or suggest colored electrodes or a plurality of colored electrodes spaced apart from one another as recited in claim 10. The Examiner's conclusory assertion that Ota '517 teaches "colored electrodes used to hide the particles in a particular voltage-bias display state, column 9, lines 1-37," is unfounded because nowhere in column 9 is either a colored electrode mentioned or any hiding of particles by an electrode mentioned.

To the extent the Examiner intended to refer to some other portion of Ota '517 to support his conclusion that Ota '517 teaches colored electrodes, his conclusion remains unsupported by any portion of Ota '517. Appellants note that at column 7, line 66 to column 8, line 48, Ota '517 discusses a "colored porous layer 12" with pores that, "must be large enough to pass the particles of the electrophoretic material 6 therethrough and small enough to hide the electrophoretic material 6 from sight." (quoting col. 8, lines 39-42). However, there is no suggestion or indication from either the text or drawings of Ota '517 that this porous layer 12 is an electrode. Rather, Ota '517 figures 2a, 2b and accompanying text show that porous layer 12 is not an electrode. Accordingly, Ota '517 does not teach or suggest even a single colored electrode because, by any reading, Ota '517 does not even mention electrodes that are themselves colored.

Furthermore, Naoyuki does not teach or suggest colored electrodes because it makes no mention of color with respect to electrodes or particles, and Appellants do not believe the Examiner asserts otherwise.

Any assertion that Ota '693 teaches colored electrodes is unsupported by any citation to Ota '693. Furthermore, Ota '693 does not disclose, teach, or suggest colored electrodes or a plurality of different colored electrodes as set forth in Appellants' claim 10. Rather, Ota '693 discloses only color overlays, not colored electrodes. In fact, Ota '693 only teaches the use of transparent electrodes that are used in conjunction with a colored overlay. Specifically, Ota '693 teaches the colored overlay is not the electrode, but rather it may be "interposed between the transparent electrode and the suspension layer.", (Ota '693, col. 7, lines 35-47) and "[t]he colored layer 50...may be electrically insulating." (Ota '693, col. 7, lines 47-49). Accordingly, in

teaching colored overlays Ota '693 does not disclose, teach, or fairly suggest colored electrodes or provide any motivation to one of ordinary skill in the art to seek a colored electrode. Instead, Ota '693 teaches away from colored electrodes by leading the ordinary artisan in a direction divergent to that taken by Appellant in claim 10. That is, Ota '693 directs the artisan to transparent electrodes. Accordingly, Ota '693 fails to teach or suggest colored electrodes and in teaching the benefit of the extra layer, namely the colored overly, with a transparent electrode, Ota '693 in fact teaches away from colored electrodes.

The overlay of Ota '693 does not "color" the underlying electrode because the color of the electrode is the same after the overlay is removed as it was before. Accordingly, the Examiner must be arguing that an electrode is a "colored electrode" because it appears to have a color when viewed through an overlay. To put it bluntly, such an argument is absurd. The Examiner's argument is equivalent to asserting that a piece of white paper is "red-colored paper" simply because the white paper is tucked into a transparent red sheet protector.

More particularly, the Examiner's argument is baseless because it ignores the plain meaning of Appellants' claims and the accepted usage of the English language. Accepted English usage would lead one of ordinary skill in the art to understand the term "colored electrodes" to refer to an electrode that is itself colored because the word "colored" is used as an adjective to denote a quality of the "electrode." Further, Appellants' application, figures and claims all support use of the term "colored electrode" as referring to an electrode that is itself colored. Accordingly, the overlays of Ota '693 do not provide "colored electrodes" as that term is used in Appellants' application, claim 10, or by one of ordinary skill in the art, because they do not change the color of the electrode itself.

Thus, for the reasons described above, Appellants respectfully submit that claim 10 is novel and nonobvious over Ota '693 in view of Naoyuki and Ota '517 because these references, either alone or in proper combination, do not teach or fairly suggest Appellants' claim 10 as a whole, and in particular, "colored electrodes," as claimed therein. Moreover, for the reasons above, Appellants submit that the Examiner has failed to establish a *prima facie* case of obviousness against claim 10. Therefore, Appellants respectfully request reversal of the rejection of claim 10.

8.6 The claimed invention is patentable under any other possible bases for rejection

Appellants believe that the foregoing arguments address each of the pending rejections of the pending claims. However, to the extent the Examiner's mention of a reference named "Saxe et al." is used as a basis for rejection, Appellants strongly urge that the Examiner's use of "Saxe et al." to support any rejection of claims 1-10, should not be permitted because it is improper and in direct violation of 37 C.F.R. § 1.104(d)(1). In particular, the Examiner fails to cite any information that would allow Appellant to identify this reference because he refers to this references simply as "Saxe et al." This directly violates 37 C.F.R. § 1.104(d)(1). See also MPEP § 707.05 (7th Ed., July 1998). The Examiner's failure to identify "Saxe et al." deprives Appellant of a fair opportunity to effectively respond to his assertions based thereon. Accordingly, Appellants respectfully request that "Saxe et al." and the Examiner's arguments based thereon be excluded from this appeal.

Nevertheless, Appellants submit the following out of an abundance of caution and without waiver or prejudice to Appellants' request to exclude the Examiner's comments based on "Saxe et al." or any future responses should "Saxe et al." be identified. To the extent that the Examiner refers to U.S. Patent No. 5,650,872 to Saxe et al. ("the '872 patent"), Appellant submits that this patent, either alone or in proper combination with Ota '693, Naoyuki, and Ota '517, does not anticipate or render obvious Appellants' claims. Appellants note that the '872 patent was asserted against Appellants' claims in a first Final Office Action dated May 23, 2000. In a Reply After Final Rejection filed July 24, 2000, Appellants fully responded to the Examiner's arguments based on the '872 patent. Subsequently, the Examiner withdrew his final rejection and issued a new Office Action dated August 29, 2000, in which the '872 patent was neither relied on nor mentioned. Appellants fully responded to the prior office action in a Response filed January 29, 2001, in which no amendments were made to Appellants claims or application. Subsequently, the Examiner issued a second Final Office Action on April 9, 2001, from which the present appeal is taken.

Specifically, Appellants have previously pointed out that the '872 patent discloses anisometric particles that respond to an electric field -not by migration- but by reorientation to become aligned. (see, e.g., the '872 patent, col. 1, lines 15-50, col. 2, lines 55-67, col. 3, lines 57-

59, col. 4, lines 8-26, and Figs. 3 and 4, item 21). This teaching of the '872 patent is distinctly different from that of Appellants application because "reorientation" does not encompass "migration" as the terms are used in the application, the '872 patent, and/or understood by those of ordinary skill in the art. Accordingly, the '872 patent does not anticipate nor render obvious Appellants' claimed inventions because the '872 patent does not disclose, teach or suggest the limitation of particle migration or that electrophoretic mobility is even a relevant property of the '872 patent's particles.

More particularly, particle orientation and/or alignment does not constitute nor inherently involve particle migration. Migration necessarily involves a translational motion as the term "migrate" is used in the application whereas orientation and/or alignment does not. For example, Webster's Ninth New Collegiate Dictionary defines "orient" as, "3: to cause the axes of the molecules of to assume the same direction" See Webster's Ninth New Collegiate Dictionary 832 (1984). This definition of "orient" is perfectly consistent with the understanding of the term by those of ordinary skill in the art and the '872 patent. As a result, a particle can "orient," or align," simply through rotational motion -no translational motion is required, inherent or implied. In contrast, the term "migrate" as used in the application and the art requires translational motion, i.e., motion from one location to another -not just simple rotation. Accordingly, Appellants respectfully submit that the '872 patent, either alone or in proper combination with Ota '693, Naoyuki, and Ota '517, does not anticipate or render obvious Appellants' claims.

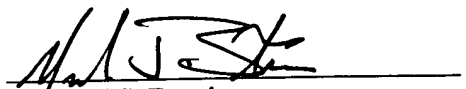
Appellants believe that the foregoing arguments address each of the pending rejections of the pending claims. In particular, the present Brief addresses each of the rejections made final in the Final Office Action. Accordingly, Appellants submit that the present application meets all requirements for patentability.

(9) Conclusion

For the reasons given above, it is respectfully requested the final rejections be reversed and the application be passed to issue with claims 1-10 as presented in the Appendix attached hereto.

A Transmittal and Fee for the filing of this Brief on Appeal, as well as a Petition and Fee for a one-month extension of time are submitted herewith. Appellants believe that the present filing necessitates no other fees. However, if any additional fees are due, the Commissioner is hereby authorized to charge any such fees to Attorney's Deposit Account No. 20-0531.

Respectfully submitted,



Date: September 12, 2001
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Fax No. (617) 248-7100

Michael J. Bastian
Attorney for Appellants
Testa, Hurwitz, & Thibeault, LLP
High Street Tower
125 High Street
Boston, MA 02110

2146090v1

APPENDIX

1. An electrophoretic display comprising:

at least one capsule containing a suspending fluid and at least a first particle and a second particle, said first particle having a first optical property and a first electrophoretic mobility and said second particle having a second optical property and a second electrophoretic mobility; and

at least two electrodes disposed adjacent said capsule;

wherein application of an electric field to said capsule by said electrodes causes said capsule to change visual state responsive to the optical properties and electrophoretic mobilities of said particles.

2. The electrophoretic display of claim 1 wherein said first electrophoretic mobility and said second electrophoretic mobility are substantially non-overlapping.

3. The electrophoretic display of claim 1 wherein said capsule contains at least one red particle, at least one blue particle, and at least one green particle.

4. The electrophoretic display of claim 1 wherein said suspending fluid is substantially transparent.

5. The electrophoretic display of claim 1 wherein said suspending fluid is dyed.

6. An electrophoretic display comprising:

a substrate;

at least one capsule containing a suspending fluid and at least one particle;

at least two electrodes disposed adjacent the at least one capsule, said at least two electrodes disposed between said substrate and said at least one capsule,

wherein application of a voltage potential to one of said at least two electrodes causes said at least one particle to migrate within said capsule, causing said capsule to change its visual state.

7. The electrophoretic display of claim 6 wherein said suspending fluid is substantially transparent.

8. The electrophoretic display of claim 6 wherein said at least one particle has an optical property matching an optical property of one of said at least two electrodes.

9. The electrophoretic display of claim 6 wherein said at least one particle is substantially white.

10. An electrophoretic display comprising:

at least one capsule containing a suspending fluid and at least one white particle;

a cyan-colored electrode disposed adjacent said capsule;

a magenta-colored electrode disposed adjacent said capsule, said magenta-colored electrode spaced apart from said cyan-colored electrode;

a yellow-colored electrode disposed adjacent said capsule, said yellow-colored electrode spaced apart from said cyan-colored electrode and said magenta-colored electrode; and

a white electrode adjacent said capsule, said white electrode spaced apart from said cyan-colored electrode, said yellow-colored electrode, and said magenta-colored electrode;

wherein application of a voltage potential to said cyan-colored electrode, magenta-colored electrode, and yellow-colored electrode causes said white particles to migrate within the capsule to locations adjacent said cyan-colored electrode, said magenta-colored electrode, and said yellow-colored electrode causing said capsule to appear white, and wherein application of a second voltage potential to said cyan-colored, said magenta-colored, and said yellow-colored electrode causes said white particles to migrate within said capsule to a location adjacent said white electrode causing said capsule to appear substantially black.

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EXHIBIT A

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ASSIGNEE:
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SERIAL NUMBER: 09140862
PATENT NUMBER:

FILING DATE: 08/27/1998
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Attorney Docket No. INK-006
(2108/13)

ASSIGNMENT

WHEREAS, I, Joseph Jacobson, have invented one or more improvements in

Color Electrophoretic Displays

described in an application (or provisional application) for Letters Patent of the United States:

☐ identified by Attorney Docket No. _____, and/or executed by me of even date herewith and about to be filed in the United States Patent Office;

☒ Serial No. 09/140,862 filed in the United States Patent Office on August 27, 1998; and

WHEREAS, E Ink Corporation (hereinafter "ASSIGNEE"), a corporation organized and existing under the laws of the State of Delaware, and having a usual place of business at 45 Spinelli Place, Cambridge, Massachusetts 02138 desires to acquire an interest therein, in accordance with agreements duly entered into with me;

NOW, THEREFORE, to all whom it may concern be it known that for and in consideration of said agreements and of other good and valuable consideration, the receipt of which is hereby acknowledged, I have sold, assigned and transferred and by these presents do hereby sell, assign and transfer unto said ASSIGNEE, its successors, assigns, and legal representatives, my entire right, title and interest in and throughout the United States of America, its territories and all foreign countries, in and to the inventions described in said application, together with my entire right, title and interest in and to said application and such Letters Patent as may issue thereon or claim priority under international convention, including but not limited to continuations, divisionals, reissues, and reexaminations of said application of such Letters Patent; said inventions, applications and Letters Patent to be held and enjoyed by said ASSIGNEE for its own use and behalf and for its successors, assigns and legal representatives, to the full end of the term for which said Letters Patent may be granted as fully and entirely as the same would have been held by me had this assignment and sale not been made; I hereby convey all of my rights arising under or pursuant to any and all international agreements, treaties or laws relating to the protection of industrial property by filing any such applications for Letters Patent. I hereby acknowledge that this assignment, being of my entire right, title and interest in and to said invention, carries with it the right in ASSIGNEE to apply for and obtain from competent authorities in all countries of the world any and all Letters Patent by attorneys and agents of ASSIGNEE's selection and the right to procure the grant of all Letters Patent to ASSIGNEE for its own name as assignee of my entire right, title and interest therein.

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IN TESTIMONY WHEREOF, I have hereunto set my hand and affixed my seal the date set forth below.

Inventor: _____
Joseph Jacobson

Dated: 6/7/99

Commonwealth of Massachusetts)
County of Middlesex) ss

Subscribed and sworn to before me, by the above-named Joseph Jacobson this 7th day of June, 1999.

_____
Notary Public
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SERIAL NUMBER: 09140862
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Joseph B Milstein — Signature

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Name	Johnathan D. Albert	2/8/99
Name	Barrett Comiskey	2/8/99
Name		/ /
Name		/ /
Name		/ /

Receiving Party ☐ Mark if additional names of receiving parties attached

Name (line 1): E Ink Corporation

Name (line 2):

Address (line 1): 45 Spinelli Place

Address (line 2):

Address (line 3): Cambridge (City) MA (State/Country) 02138 (Zip Code)

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Name: Patent Administrator

Address (line 1): Testa, Hurwitz & Thibeault, LLP

Address (line 2): High Street Tower

Address (line 3): 125 High Street

Address (line 4): Boston, MA 02110

Pages Enter the total number of pages of the attached conveyance document including any attachments. 2

Application Number(s) or Patent Number(s)

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Enter either the Patent Application Number or the Patent Number (DO NOT ENTER BOTH numbers for the same property).

Patent Application Number(s)			Patent Number(s)		
09/140,862					

Patent Cooperation Treaty (PCT)

Enter PCT application number only if a U.S. Application Number has not been assigned.

PCT | PCT | PCT

PCT | PCT | PCT

Number of Properties

Enter the total number of properties involved. # 1

Fee Amount

Fee Amount for Properties Listed (37 CFR 3.41): $ 40

Method of Payment: Enclosed ☒ Deposit Account ☐

Deposit Account

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Authorization to charge additional fees: Yes ☐ No ☒

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JOSEPH B. MILSTEIN	Joseph B Milstein	2/26/99
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Attorney Docket No.
INK-006
(2108/13)

ASSIGNMENT

WHEREAS, We, Jonathan D. Albert and Barrett Comiskey have invented one or more improvements in:

Color Electrophoretic Displays

described in an application (or provisional application) for Letters Patent of the United States:

☐ identified by Attorney Docket No. INK-006, and/or executed by us of even date herewith and about to be filed in the United States Patent Office;

☒ Serial No. 09/140,862 filed in the United States Patent Office on 08/27/98; and

WHEREAS, E Ink Corporation (hereinafter "ASSIGNEE"), a corporation organized and existing under the laws of the State of Delaware, and having a usual place of business at 45 Spinelli Place, Cambridge, MA 02138 desires to acquire an interest therein, in accordance with agreements duly entered into with us;

NOW, THEREFORE, to all whom it may concern be it known that for and in consideration of said agreements and of other good and valuable consideration, the receipt of which is hereby acknowledged, we have sold, assigned and transferred and by these presents do hereby sell, assign and transfer unto said ASSIGNEE, its successors, assigns, and legal representatives, our entire right, title and interest in and throughout the United States of America, its territories and all foreign countries, in and to the inventions described in said application, together with our entire right, title and interest in and to said application and such Letters Patent as may issue thereon or claim priority under international convention, including but not limited to continuations, divisionals, reissues, and reexaminations of said application of such Letters Patent; said inventions, applications and Letters Patent to be held and enjoyed by said ASSIGNEE for its own use and behalf and for its successors, assigns and legal representatives, to the full end of the term for which said Letters Patent may be granted as fully and entirely as the same would have been held by us had this assignment and sale not been made; we hereby convey all of our rights arising under or pursuant to any and all international agreements, treaties or laws relating to the protection of industrial property by filing any such applications for Letters Patent. We hereby acknowledge that this assignment, being of our entire right, title and interest in and to said inventions, carries with it the right in ASSIGNEE to apply for and obtain from competent authorities in all countries of the world any and all Letters Patent by attorneys and agents of ASSIGNEE's selection and the right to procure the grant of all Letters Patent to ASSIGNEE for its own name as assignee of our entire right, title and interest therein.

AND, we hereby further agree for ourselves and our executors and administrators to execute upon request any other lawful documents and likewise to perform any other lawful acts which may be deemed necessary to secure fully the aforesaid invention to said ASSIGNEE, its successors, assigns, and legal representatives, but at its or their expense and charges, including: the execution of applications for patents in foreign countries; the execution of substitution, reissue, divisional or continuation applications; and preliminary or other statements or the giving of testimony in any interference or other proceeding in which said inventions or any application or patent directed thereto may be involved; and

we further hereby authorize ASSIGNEE or its attorneys or agents to insert the correct serial number and filing date into this assignment, if none is indicated on that date of our execution of this assignment;

AND, we do hereby authorize and request the Commissioner of Patents of the United States to issue such Letters Patent as shall be granted upon said application or applications based thereon to said ASSIGNEE, its successors, assigns, and legal representatives.

IN TESTIMONY WHEREOF, we have hereunto set our hands and affixed our seals the date set forth below.

Inventor: _____
Jonathan D. Albert

Commonwealth of Massachusetts)
County of) ss

Subscribed and sworn to before me, by the above-named Jonathan D. Albert this 8th day of February, 1999.

_____
Notary Public: John D. Lanza
My Commission Expires: July 29, 2005

Inventor: _____
Barrett Comiskey

Commonwealth of Massachusetts)
County of) ss

Subscribed and sworn to before me, by the above-named Barrett Comiskey this 8th day of February, 1999.

_____
Notary Public: John D. Lanza
My Commission Expires: July 29, 2005

EXHIBIT B

organ of Cor·ti \-'kȯrt-ē\ [Alfonso *Corti* †1876 Ital. anatomist] (1882) : a complex epithelial structure in the cochlea that rests on the internal surface of the basilar membrane and in mammals is the chief part of the ear by which sound is directly perceived

or·gan·o·gen·e·sis \ˌȯr-gə-nō-'jen-ə-səs, ȯr-ˌgan-ə-\ *n* [NL] (cā. 1860) : the origin and development of bodily organs — compare MORPHOGENESIS — **or·gan·o·ge·net·ic** \-jə-'net-ik\ *adj* — **or·gan·o·ge·net·i·cal·ly** \-i-k(ə-)lē\ *adv*

or·gan·o·lep·tic \ˌȯr-gə-nō-'lep-tik, ȯr-ˌgan-ə-\ *adj* [F *organoleptique*, fr. *organ-* + Gk *lēptikos* disposed to take, fr. *lambanein* to take — more at LATCH] (1852) 1 : being, affecting, or relating to qualities (as taste, color, odor, and feel) of a substance (as a food or drug) that stimulate the sense organs 2 : involving use of the sense organs ⟨~ evaluation of foods⟩ — **or·gan·o·lep·ti·cal·ly** \-ti-k(ə-)lē\ *adv*

or·gan·ol·o·gy \ˌȯr-gə-'näl-ə-jē\ *n* [ISV] (ca. 1842) : the study of the organs of plants and animals

or·gano·mer·cu·ri·al \ȯr-ˌgan-ō-(ˌ)mər-'kyůr-ē-əl\ *n* (1938) : an organic compound or a pharmaceutical preparation containing mercury

or·gano·me·tal·lic \-mə-'tal-ik\ *adj* [ISV] (1852) : of, relating to, or being an organic compound that usu. contains a metal or metalloid bonded directly to carbon — **organometallic** *n*

or·ga·non \'ȯr-gə-ˌnän\ *n* [Gk, lit., tool — more at ORGAN] (1543) : an instrument for acquiring knowledge; *specif* : a body of principles of scientific or philosophic investigation

or·gano·phos·phate \ȯr-ˌgan-ə-'fās-ˌfāt\ *n* (1949) : an organophosphorus pesticide — **organophosphate** *adj*

or·gano·phos·pho·rus \-'fäs-f(ə-)rəs\ *also* **or·gano·phos·pho·rous** \-fäs-'fōr-əs, -'fȯr-\ *adj* (1950) : of, relating to, or being a phosphorus-containing organic pesticide (as malathion) that acts by inhibiting cholinesterase — **organophosphorus** *n*

organ–pipe cactus *n* (1908) : any of several tall upright cacti of the southwestern U.S. and adjacent Mexico: as **a** : SAGUARO **b** : a cactus (*Lemnaireocereus marginatus* or *Pachycereus marginatus*) that branches at the base to form several ridged upright stems and bears 2-inch red and greenish white flowers

or·ga·num \'ȯr-gə-nəm\ *n* [ML, fr. L, organ] (1614) 1 : ORGANON 2 : early polyphony of the late Middle Ages that consists of one or more voice parts accompanying the cantus firmus in parallel motion usu. at a fourth, fifth, or octave above or below; *also* : a composition in this style

or·gan·za \ȯr-'gan-zə\ *n* [prob. alter. of *Lorganza*, a trademark] (1820) : a sheer dress fabric resembling organdy and usu. made of silk, rayon, or nylon

or·gan·zine \'ȯr-gən-ˌzēn\ *n* [F or It; F *organsin*, fr. It *organzino*] (1699) : a raw silk yarn used for warp threads in fine fabrics

or·gasm \'ȯr-ˌgaz-əm\ *n* [NL *orgasmus*, fr. Gk *orgasmos*, fr. *organ* to grow ripe, be lustful: akin to Skt *ūrjā* sap, strength] (1763) : intense or paroxysmal emotional excitement; *esp* : the climax of sexual excitement typically occurring toward the end of coitus — **or·gas·mic** \ȯr-'gaz-mik\ *also* **or·gas·tic** \-'gas-tik\ *adj*

or·geat \'ȯ(ə)r-ˌzhä(t)\ *n* [F, fr. MF, fr. *orge* barley, fr. L *hordeum;* akin to OHG *gersta* barley, Gk *krī*] (1754) : a sweet almond-flavored nonalcoholic syrup used as a cocktail ingredient or food flavoring

or·gi·as·tic \ˌȯr-jē-'as-tik\ *adj* [Gk *orgiastikos*, fr. *orgiazein* to celebrate orgies, fr. *orgia*] (1698) 1 : of, relating to, or marked by orgies 2 : characterized by unrestrained emotion — **or·gi·as·ti·cal·ly** \-ti-k(ə-)lē\ *adv*

or·gone \'ȯ(ə)r-ˌgōn\ *n* [prob. fr. *orgasm* + *-one* (as in *hormone*)] (1942) : a vital energy held to pervade nature and to be made available for use by the human body by sitting in a specially designed box

or·gu·lous \'ȯr-g(y)ə-ləs\ *adj* [ME, fr. OF *orgueilleus*, fr. *orgueil* pride, of Gmc origin; akin to OHG *urguol* distinguished] (13c) : PROUD

or·gy \'ȯr-jē\ *n, pl* **orgies** [MF *orgie*, fr. L *orgia*, pl., fr. Gk; akin to Gk *ergon* work — more at WORK] (1589) 1 : secret ceremonial rites held in honor of an ancient Greek or Roman deity and usu. characterized by ecstatic singing and dancing 2 **a** : drunken revelry **b** : an excessive sexual indulgence (as at a wild party) 3 : something that resembles an orgy in lack of control or moderation ⟨soldiers engaging in an ~ of destruction⟩

-oria *pl of* -ORIUM

-o·ri·al \'ōr-ē-əl, 'ȯr-\ *adj suffix* [ME, fr. L *-orius* -ory + ME *-al*] : of, belonging to, or connected with ⟨combinat*orial*⟩

ori·ba·tid \ȯ-'rib-ət-əd, ˌȯr-ə-'bat-əd\ *n* [NL *Oribatidae* (coextensive with *Oribatoidea*), fr. *Oribata*, genus name, fr. Gk *oribatēs* walking the mountains, fr. *oros* mountain + *-batēs*, fr *bainein* to go — more at RISE, COME] (1948) : any of a superfamily (Oribatoidea) of small oval eyeless nonparasitic mites having a heavily sclerotized integument with a leathery appearance — **oribatid** *adj*

ori·el \'ōr-ē-əl, 'ōr-\ *n* [ME, porch, oriel, fr. MF *oriol* porch] (14c) : a large bay window projecting from a wall and supported by a corbel or bracket

¹ori·ent \'ōr-ē-ənt, 'ōr-, -ē-ˌent\ *n* [ME, fr. MF, fr. L *orient-, oriens*, fr. prp. of *orīri* to rise — more at RISE] (14c) 1 *archaic* : EAST 1b 2 *cap* : EAST 2 3 **a** : a pearl of great luster **b** : the luster or sheen of a pearl

²orient *adj* (15c) 1 *archaic* : ORIENTAL 1 2 **a** : LUSTROUS, SPARKLING ⟨~ gems⟩ **b** *archaic* : RADIANT, GLOWING 3 *archaic* : rising in the sky

³ori·ent \'ōr-ē-ˌent, 'ōr-\ *vt* [F *orienter*, fr. MF, fr. *orient*] (1727) 1 **a** : to cause to face or point toward the east; *specif* : to build (a church or temple) with the longitudinal axis pointing eastward and the chief altar at the eastern end **b** : to set or arrange in any determinate position esp. in relation to the points of the compass **c** : to ascertain the bearings of 2 **a** : to set right by adjusting to facts or principles **b** : to acquaint with the existing situation or environment 3 : to cause the axes of the molecules of to assume the same direction

ori·en·tal \ˌōr-ē-'ent-ᵊl, ˌōr-\ *adj* (14c) 1 *often cap* : of, relating to, or situated in the Orient 2 **a** : of superior grade, luster, or value **b** : being corundum or sapphire but simulating another gem in color 3 *often cap* : of, relating to, or having the characteristics of Orientals 4 *cap* : of, relating to, or constituting the biogeographic region that includes Asia south and southeast of the Himalayas and the Malay archipelago west of Wallace's line — **ori·en·tal·ly** \-ᵊl-ē\ *adv*

Oriental *n* (15c) : a member of one of the indigenous peoples of the Orient

oriental fruit moth *n* (1921) : a small nearly cosmopolitan moth (*Grapolitha molesta*) prob. of Japanese origin whose larva is injurious to the twigs and fruit of orchard trees and esp. the peach — called also *oriental peach moth*

ori·en·tal·ism \ˌōr-ē-'ent-ᵊl-ˌiz-əm\ *n, often cap* (1769) 1 : a trait, custom, or habit of expression characteristic of oriental peoples 2 : scholarship or learning in oriental subjects — **ori·en·tal·ist** \-ᵊl-ist\ *n, often cap*

ori·en·tal·ize \-ᵊl-ˌīz\ *vb* **-ized; -iz·ing** *vt, often cap* (1823) : to make oriental ~ *vi, often cap* : to become oriental

Oriental poppy *n* (1731) : an Asian perennial poppy (*Papaver orientale*) that is commonly cultivated for its large showy flowers

Oriental rug *n* (1881) : a handwoven or hand-knotted one-piece rug or carpet made in the Orient — called also *Oriental carpet*

ori·en·tate \'ōr-ē-ən-ˌtāt, 'ōr-, -ˌen-\ *vb* **-tat·ed; -tat·ing** *vt* (1849) : ORIENT ~ *vi* : to face or turn to the east

ori·en·ta·tion \ˌōr-ē-ən-'tā-shən, ˌōr-, -ˌen-\ *n* (1849) 1 **a** : the act or process of orienting or of being oriented **b** : the state of being oriented; *broadly* : ARRANGEMENT, ALIGNMENT 2 : a usu. general or basic direction of thought, inclination, or interest 3 : change of position by organs, organelles, or organisms in response to external stimulus — **ori·en·ta·tion·al** \-shnəl, -shən-ᵊl\ *adj* — **ori·en·ta·tion·al·ly** \-ē\ *adv*

ori·ent·ed \'ōr-ē-ˌent-əd, 'ōr-\ *adj* (1944) : intellectually or emotionally directed ⟨humanistically ~ scholars⟩

ori·en·teer·ing \ˌōr-ē-ən-'ti(ə)r-iŋ, ˌōr-, -ˌen-\ *n* [modif. (influenced by *-eer*) of Sw *orientering*, fr. *orientera* to orient] (1948) : a cross-country race in which each participant uses a map and compass to navigate his way between checkpoints along an unfamiliar course

or·i·fice \'ȯr-ə-fəs, 'är-\ *n* [ME, fr. MF, fr. LL *orificium*, fr. L *or-*, *os* mouth — more at ORAL] (15c) : an opening (as a vent, mouth, or hole) through which something may pass — **or·i·fi·cial** \ˌȯr-ə-'fish-əl, ˌär-\ *adj*

ori·flamme \'ȯr-ə-ˌflam, 'är-\ *n* [ME *oriflamble*, the banner of St. Denis, fr. MF, fr. ML *aurea flamma*, lit., golden flame] (1600) : a banner-like symbol, or ideal inspiring devotion or courage

ori·ga·mi \ˌȯr-ə-'gäm-ē\ *n* [Jp, folded paper, fr. *ori* folding] (1956) : the art or process of Japanese paper folding

orig·a·num \ə-'rig-ə-nəm\ *n* [ME, fr. L, wild marjoram, fr. Gk *origanon*] (12c) : any of various fragrant aromatic plants of the mint or verbena families used as seasonings; *esp* : OREGANO 1

or·i·gin \'ȯr-ə-jən, 'är-\ *n* [ME *origine*, prob. fr. MF, fr. L *origin-, origo*, fr. *oriri* to rise — more at RISE] (15c) 1 : ANCESTRY, PARENTAGE 2 **a** : rise, beginning, or derivation from a source **b** : the point at which something begins or rises or from which it derives ⟨the ~ of the custom is lost in the mist of time⟩; *also* : something that creates, causes, or gives rise to another ⟨this spring is the ~ of the brook⟩ 3 : the more fixed, central, or larger attachment of a muscle 4 : the intersection of coordinate axes

syn ORIGIN, SOURCE, INCEPTION, ROOT mean the point at which something begins its course or existence. ORIGIN applies to the things or persons from which something is ultimately derived and often to the causes operating before the thing itself comes into being; SOURCE applies more often to the point where something springs into being; INCEPTION stresses the beginning of something without implying causes; ROOT suggests a first, ultimate, or fundamental source often not easily discerned.

¹orig·i·nal \ə-'rij-ən-ᵊl, -'rij-nəl\ *n* (14c) 1 *archaic* : the source or cause from which something arises; *specif* : ORIGINATOR 2 **a** : that from which a copy, reproduction, or translation is made **b** : a work composed firsthand 3 **a** : a person of fresh initiative or inventive capacity **b** : an eccentric person

²original *adj* (14c) 1 : of, relating to, or constituting an origin or beginning : INITIAL ⟨the ~ part of the house⟩ 2 **a** : not secondary, derivative, or imitative **b** : being the first instance or source from which a copy, reproduction, or translation is or can be made 3 : independent and creative in thought or action : INVENTIVE *syn* see NEW — **original·ly** \-ē\ *adv*

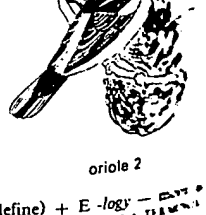
orig·i·nal·i·ty \ə-ˌrij-ə-'nal-ət-ē\ *n* (1742) 1 : the quality or state of being original 2 : freshness of aspect, design, or style 3 : the power of independent thought or constructive imagination

original sin *n* (14c) : the state of sin that according to Christian theology characterizes all human beings as a result of Adam's fall

orig·i·nate \ə-'rij-ə-ˌnāt\ *vb* **-nat·ed; -nat·ing** *vt* (1657) : to give rise to : INITIATE ~ *vi* : to take or have origin : BEGIN *syn* see SPRING — **orig·i·na·tion** \-ˌrij-ə-'nā-shən\ *n* — **orig·i·na·tor** \-'rij-ə-ˌnāt-ər\ *n*

orig·i·na·tive \ə-'rij-ə-ˌnāt-iv, -nət-\ *adj* (1827) : having ability to originate : CREATIVE — **orig·i·na·tive·ly** *adv*

O–ring \'ō-ˌriŋ\ *n* (1946) : a ring (as of synthetic rubber) used as a gasket



oriole 2

ori·ole \'ōr-ē-ˌōl, 'ōr-, -ē-əl\ *n* [F *oriol*, fr. L *aureolus*, dim. of *aureus* golden, fr. *aurum* gold; akin to Lith *auksas* gold] (1776) 1 : any of a family (Oriolidae) of usu. brightly colored Old World passerine birds related to the crows 2 : any of a family (Icteridae) of New World passerine birds of which the males are usu. bright black and yellow or orange and the females are chiefly greenish or yellowish

Ori·on \ə-'rī-ən, ō-\ *n* [L, fr. Gk *Ōriōn*] 1 : a giant hunter slain by Artemis in Greek mythology 2 [L (gen. *Orionis*)] : a constellation on the equator east of Taurus represented on charts by the figure of a hunter with belt and sword

or·is·mol·o·gy \ˌōr-əz-'mäl-ə-jē, ˌär-\ *n* [Gk *horismos* definition (fr. *horizein* to define) + E *-logy* — more at HORIZON] (1816) : the science of defining technical terms : TERMINOLOGY — **or·is·mo·log·i·cal** \ˌōr-əz-mə-'läj-i-kəl, ˌär-; ō-ˌriz-\ *adj*

or·i·son \'ȯr-ə-sən, 'är-, -zən\ *n* [ME, fr. OF, fr. LL *oration-, oratio*] (12c) : PRAYER

-o·ri·um \'ōr-ē-əm, 'ōr-\ *n suffix, pl* **-oriums** *or* **-o·ria** \-ē-ə\ [L, fr. neut. of *-orius* -ory] : ¹-ORY ⟨hausto*rium*⟩

A
B

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